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12

TEST AND EVALUATION OF A FEASIBILITY MODEL ILS GLIDE SLOPE PERFORMANCE ASSURANCE MONITOR FOR THE FINAL APPROACH PATH

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FINAL REPORT

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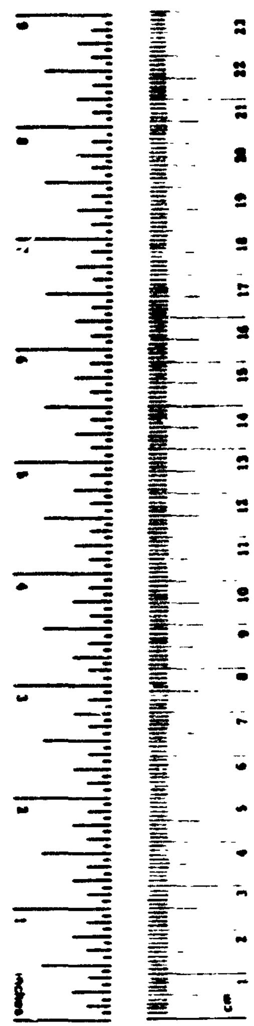
NOTICE

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

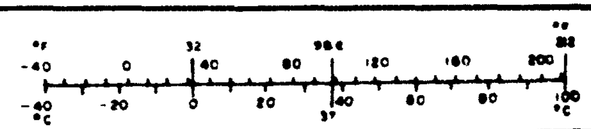
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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16. Abstract

The second of two test and evaluations was performed at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, to determine the feasibility of a ground-based monitoring system to accurately measure the flight-path of selected aircraft on the final approach path. This tracking information would provide a data base for statistical analysis of the instrument landing system (ILS) glide slope performance. This subsystem was tested by comparison of its measured glide slope angle with the glide slope angle generated by the NAFEC phototheodolite tracking system (time referenced). The data analysis indicates this glide slope monitor feasibility model was not adequate to perform as an ILS performance assurance monitor. The other test and evaluation is reported in FAA-RD-74-66, dated April 1974.

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PREFACE

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Mr. Joseph Harrigan, Air Traffic Controller, Landing Branch, Communications and Guidance Division, for his assistance at the local ATC Tower during the flight tests.

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INTRODUCTION

PURPOSE.

The purpose of this project was to test and evaluate the second of two feasibility model instrument landing system (ILS) glide slope monitoring subsystems to determine its aircraft position measuring accuracy along the final approach path.

BACKGROUND.

Flight Standards Service (FS-1) requested Systems Research and Development Service (SRDS) on November 21, 1969, to obtain the Aircraft Landing Measurement System (ALMS) from England, on a loan basis for assessing Category II and category III operations. The ALMS system was to be installed at Dulles International Airport for an operational evaluation. The ALMS system was not an all-weather type and only measured aircraft position at a few points on the final approach path. The system was never sent to the United States due to its nonavailability.

ILS facilities provide alignment and descent guidance information during aircraft landing for the final approach path. During this phase of aircraft flight, they are operating at near-critical speeds, over decreasing terrain clearances, and in all-weather conditions. Therefore, it is important that the quality of these ILS signals be monitored accurately in terms of alignment, stability, amplitude, and course structure. The quality of the radiated ILS signal may be adversely affected by terrain interference, man-made obstructions, taxiing aircraft, and weather. These factors may not all be detected by "near-field" monitors which are currently in use. Flight inspection aircraft offer the best "far-field" monitor system available today. However, these specially equipped aircraft check the ILS at each airport only every 3 or 4 months, thereby imposing a serious time lag in the ILS "far-field" monitor system that is available today as well as being a great financial burden.

In attempting to develop an all-weather final approach path aircraft measuring system as well as an ILS monitoring system, SRDS distributed a Request For Proposals (RFP). The RFP was based on the concept of measuring selected user aircraft trajectories and statistically analyzing these to determine if the ILS alignment had deviated from an acceptable amount. This technique is valid provided the sample is large enough to average out random errors. Many proposals were submitted by private contractors.

Due to the requirements of ILS monitoring and aircraft position measuring under all-weather conditions and the desirability of not adding additional avionics equipment to the user aircraft, only the Westinghouse Electric Company (WE Co.) (DOT-FA72-WA2837) and Airborne Instruments Laboratory (AIL Co.) Division of Cutler-Hammer Systems (DOT-FA72-WA2849) proposals were considered technically acceptable by the proposal evaluation team consisting of representatives of SRDS, FS-1, Airways Facilities (AF) and the National Aviation Facilities Experimental Center (NAFEC). The systems proposed also have the potential for determining pilot warnings when the aircraft is below a safe altitude envelope.

The AIL Co. system was tested and evaluated at NAFEC: the results were given in report FAA-RD-74-66, dated April 1974. This report describes only the WE Co. system test and evaluation. Due to several cost overruns and the eventual depletion of available contract dollars approved and allocated to this effort, only the glide slope monitor subsystem was built to completion by WE Co. and later installed at NAFEC.

DISCUSSION

THEORY OF OPERATION.

The glide slope monitor subsystem employs a monopulse phase comparison concept, as indicated in figures 1 and 2. The antenna consists of two separate inline antennas which receive the same radiofrequency (RF) pulse. The phase difference developed by the two receiving antennas is a measure of the RF signal angle off boresight for the radiation source (user aircraft transponder antenna). In figure 2, the phase difference can be seen to be equal to zero for an aircraft on boresight (approximately 3° for the glide slope).

The overall system block diagram depicting the tie-in between the user aircraft, the airport surveillance radar (ASR), the air traffic control (ATC) tower (terminal building), and the ILS glide slope monitor subsystem is shown in figure 3. The glide slope monitor monopulse receiving antenna was installed adjacent to the commissioned glide slope transmitting antenna but farther offset from it by approximately 100 feet (30.481 meters), and the monitor antenna system is tilted back so that the boresight axis is aligned with the ILS glide slope of approximately 3°. The glide slope monitor antenna is tilted sideways toward the runway by approximately 1° and 45 minutes (≈1.75°) to account for the sideways offset from the runway centerline, thereby improving the monitor's close-in measurement accuracy.

The antenna consists of individual distribution networks built of a low dielectric constant microstrip. The antenna array consists of two subarrays of 17 dipoles each; one subarray on each side of the antenna array (figure 4). The sum circuit is on one side of the stripline divider board, while the difference circuit is on the other side of the board. The glide slope monitor monopulse antenna consists of a collinear array of 34 vertical dipoles. The antenna is approximately 32 feet (≈9.75 meters) long, and its bottom is approximately 3 feet (≈1 meter) off the ground. The 17th dipole of each subarray is physically mounted in an outrigger (extension) of the main antenna. It was added based on experimental antenna range data of the main antenna. The outrigger was built because it was the cheaper approach to suppressing the first difference sidelobe to 42 decibels (dB) below the main lobe sum.

The glide slope monitor antenna has a vertical half-power beam width of 2.5° and sidelobes which are 30 dB down from the peak of the antenna patterns. The combination of the narrow vertical beamwidth, low sidelobes and the height of the antenna above ground minimize ground reflection errors. The antenna array patterns are shown in figure 5. The sum (Σ) of the signal from all dipoles is

plotted versus the difference (Δ) from a top array of dipoles minus a bottom array of dipoles. The monopulse angle measurement is made from the leading edge of the first pulse of the received aircraft ATC beacon transponder reply so that the multipath reflections from various objects such as hangars, terminal, aircraft, etc., cause minimum errors.

To meet the desired system angular accuracy and resolution requirements, the amplitude ratio between the Σ and Δ channels is measured by converting to a phase difference (ϕ) (figure 6). The antenna difference output is then rotated 90 electrical phase degrees and vectorially added to the channel by a commutating hybrid circuit in the hybrid coupler box. The hybrid coupler also converts the initial amplitude difference into a phase difference. The system phase accuracy is preserved and the drift effects are offset by alternately a''ing the difference signals at ±90 electrical phase degrees.

The two vector signals are processed by the monopulse receiver (figure 7). The zero crossings of the intermediate frequency (IF) signal are converted to binary pulses which are used to start and stop a high-speed binary counter. The binary count retained by the counter is directly proportional to initial amplitude ratio between the signal amplitude appearing at the Σ and Δ antenna terminals. The digital output is fed into two separate zero-crossing detector channels and by means of a digital-to-analog converter is displayed on a storage oscilloscope. All of the raw data are time buffered and recorded on a standard punched paper tape.

The glide slope monitor subsystem has a data burst rate of approximately 4 seconds, based on the ASR scan rate of approximately 15 revolutions per minute (r/min), that provides data points approximately every 1,000 feet (≈304.81 meters) along the final approach path which corresponds to airspeeds of approximately 150 knots (250 ft/s) (76.2 meters/s) at approximately 8 to 9 nautical miles (nmi) (≈14.82 to 16.67 kilometers) from the runway threshold. Thus, every 4 seconds, a burst lasting approximately 50 milliseconds, equal to 20 ATC beacon replies, is received. These individual measurements are digitally recorded on punched paper tape. Offline and at a later time, the individual measurements are statistically processed and for each received burst, a single off-boresight angle measurement is developed; one per ASR scan. Thus, the glide slope monitor monopulse antenna and receiver would determine the angular deviation of the user aircraft from the ILS glide slope. In performance monitoring of the ILS glide slope, a statistical analysis of all recorded flights would fill the data gaps.

In order to reduce interference, the receiver processor is activated only when the ASR is illuminating the angular sector (309 to 014° true) of the glide slope receiver antenna covering the final approach path from beyond the outer marker (OM) to the runway threshold as shown in figure 8. The beacon pretrigger (t_o), north mark (NM), and azimuth change pulses (ACP) from the ASR-4 are received at the glide slope monitor site. The NM and ACP are used to establish the glide slope monitor receiver angle gating times (approximately 1/8 of the ASR-4 scan). Time gating is also employed which is referenced from the t_o pulse so as only to receive replies from threshold to 10 nmi (18.52 kilometers) in range.

The receiver has "search" and "track" modes. Upon receiving two successive returns, the receiver shifts from the "search" mode to the "track" mode. In the "track" mode, the receiver will accept only signals having a normal period of the interrogating radar with an additional ±125 feet (±38.1 meters) timing gate. The receiver automatically reverts to the search mode for each antenna scan. Therefore, the first two returns of each ASR-4 scan will always be in the search mode. The range accuracy is minimized to approximately ±500 feet (±152.4 meters) if the system is completely aligned in range. The minimum inaccuracy is due to jitter in the signal of the transponder reply.

DESCRIPTION OF EQUIPMENT.

The glide slope monitor site equipment and its relationship to other collocated equipment is shown in figure 9. In the center of the photograph, the 26-foot (7.925 meters) long main section of the monopulse antenna is shown supported by a two piece frangible 26-foot-long (7.925 meters), 3,000-pound (1360.8 kilograms) steel I-beam bolted to a NAFEC-constructed concrete pad that was built to contractor specifications. The antenna outriggers are clearly indicated, with the bottom outrigger clearing the ground by approximately 3 feet (0.91443 meter) A standard dual red warning lamp is located at the top of the I-beam.

A steel all-weather enclosure (6 feet x 4 feet x 2 feet) (1.82886 meter x 1.21924 meter x 0.60962 meter) contains the glide slope monitor receiver and recording equipments. This enclosure has an upper and lower RF and particle-filtered vents on each side which are open when the subsystem is in use.

The signal-receiving conditioning equipment for the ASR-4 synchronization and NAFEC range real timing signals that are necessary for the glide slope monitor subsystem are contained in the trailer. The trailer also provides space for test personnel to escape the weather.

The category III ILS glide slope system with antenna is located on the right-hand side of figure 9. A microwave landing system (MLS) elevation site is located between the two aforementioned elevation parameter subsystems.

In figure 10, the monopulse antenna sideways rotation of 1°, 45 minutes, 11.0 seconds (1.75305556°) toward the runway centerline is clearly indicated. Nearby, toward the right of the photograph, is a portion of a weather transmissometer system.

In figure 11, the 3°, 0 minutes, 0.0 seconds (3.0°) forward and upward antenna rotation is shown making the monopulse antenna boresight aligned with the 3° ILS glide slope. The slightly to-the-rear site offsets from the category III ILS glide slope for the collocated systems are clearly indicated.

In figure 12, the front view of the all-weather receiver enclosure with front doors open is shown. Two side-by-side 19-inch (0.48260 meters) racks are indicated. The right-hand-side rack is radiofrequency interference (RFI) protected. Further RF shielding and isolation for the RF-IF receiver was provided by adding a vertical, top-to-bottom, steel bulkhead in the center of

the cabinet. On this wall, the angles and brackets were electrically bonded to the cabinet walls. RF feed-through was incorporated between the two halves of the cabinet in this wall. Separate thermostatically controlled heaters and fans were in each of the cabinet halves. Thermal insulation was increased in the cabinet by cementing 1-inch thick foam rubber on all internal surfaces of the cabinet walls. The functions of each rack are labeled in figure 12.

In figures 13, 14, and 15, a closeup view of the upper and lower left-hand quarters and the right-hand center, respectively, of the front view of the receiver cabinet are shown. The titles to the indicators, switches, test points and control knobs are readable in most cases.

In figure 16, the receiver cabinet rear view with rear doors open is shown. The left side is RFI protected. On the right side, at the bottom, the empty case for the electrical heater unit is shown. Opposite it, there is another black-colored unit which is the blower.

In figure 17, a 19-inch rack is shown that was located inside the trailer. It contains the signal conditioning utilized for preparing the ASR-4 t_0 signal for the glide slope monitor's use. Portions of the video trigger distribution amplifier (type FA-8927) and the line compensator amplifier (type FA-8926) were required for final shaping of the t_0 pulse. The NM, ACP, and serial timing signals were received with 1:1 pulse transformers.

In figure 18, the glide slope monitor receiving equipments are indicated in a block diagram. Similarly, the RF and IF receiving units are shown in figures 19 and 20, respectively.

INSTALLATION OF EQUIPMENT.

The contractor delivered all of the glide slope monitor equipment to the NAFEC site on May 16, 1974. NAFEC heavy equipment operators, with their unloading equipment, removed the glide slope monitor subsystem from the delivery truck and placed it on wooden feet on the ground. On May 22 and 23, 1974, under the guidance of WE Co. personnel, the NAFEC heavy equipment operators and equipment constructed the physical installation of the glide slope monitor at the site. The contractor's civil engineer guided the physical alignment of the monopulse antenna, and later, surveyed it.

The contractor personnel were at NAFEC from June 25, 1974, to June 28, 1974, and from July 29, 1974, to August 1, 1974, during which times they mechanically and electronically checked out and aligned the glide slope monitor subsystem. During the second time period, static alignment tests were accomplished using surveyed locations (x,y,z) in the monitor antenna's far field, locations on runway 13 and its taxiway, and a truck containing a beacon transponder with a Z-axis variable omniantenna attached to a 41-foot (12.4972 meter) mast. On August 1, 1974, the search/track mode data indicator was determined to be meaningless. Its effect on data reduction was not yet known.

On July 25, 1974, the contractor's antenna experts were at NAFEC, at which time they inspected and improved the mechanical connections and alignments of the monopulse antenna on the I-beam support. NAFEC heavy equipment operators and equipment were utilized by the contractor personnel this day.

From October 21, 1974 to October 22, 1974, the contractor's digital circuit design experts were at NAFEC at which time they installed and checked out new search/track mode circuitry.

Later the effect of the search/track mode indicator in the data reduction was determined to be significantly helpful in the offline data reduction process. Thus, the new search/track mode circuitry installation completed the contractor's installation of the glide slope monitor subsystem.

TEST AND EVALUATION METHODOLOGY

METHOD FOR TESTS.

The test program was divided into two categories, i.e., laboratory test and flight tests. The laboratory test, monitored by NAFEC program area personnel, was performed by the contractor during May 7 through May 9, 1974, in Baltimore, Maryland. The purpose of laboratory testing was for the contractor to demonstrate his compliance with the procurement specifications and provide a measure for comparison in the event the contractor equipment deteriorated during the installation or later during the flight tests.

The flight tests were divided into two phases; namely, contractor-controlled tests and NAFEC-controlled tests. The contractor required an airborne test target during his installation work. A minimal number of flights were required. The NAFEC-controlled tests were made to determine the statistical error values for the glide slope monitor subsystem. The original NAFEC flight test program required 27 flight hours on one target aircraft. Two aircraft were actually flown; a Gulfstream One (N-377) (figure 21) for approximately 15 flight hours and a Comanche (N-9093P) (figure 22) for approximately 11 flight hours. All NAFEC tests were performed by NAFEC personnel.

The ILS glide slope flightpath was flown approximately 30 times by each aircraft because this region of the glide slope monitor antenna pattern was the most accurate. Off-of-the-glide-slope flights and a number of level flights along the length of the ILS glide slope flightpath were flown by N-377. Additional flights were planned for N-377; however, the data reduction in the middle of N-377's flight tests indicated relatively poor performance by the glide slope monitor subsystem, dictating an analysis of the operation of the equipment on site, which eventually was accomplished by the contractor. The flight tests were halted February 20, 1975, until the contractor equipment analysis was completed on August 16, 1975. At that time, due to the lack of contractual funds, NAFEC, together with SRDS, decided to discontinue the remaining planned flight tests, and to complete the data analysis and reporting of the previously collected data.

The glide slope monitor subsystem data were real-time correlated with the ground-based space position measurements by the phototheodolite facility. This facility developed computer-type data, and it had photographic data only as backup data. The photographic data were not used in this effort. Computer programs compatible with the IBM 7090 computer were developed by NAFEC that reduced, merged, and statistically analyzed all the ground-based data.

PROCEDURES AND CONDITIONS FOR TESTS.

The laboratory test was conducted by the contractor, with the NAFEC personnel only monitoring the test. The test was conducted under controlled laboratory conditions, which demonstrated the proper operation of the glide slope monitor subsystem, as stated in the contract specifications.

NAFEC constructed, to contractor specification, two concrete pads at a contractor-requested and NAFEC-approved site. NAFEC supplied electrical power, contractor equipment installation assistance and equipment, ASR-4 facility synchronization signals via landlines, ground-to-air communications, a shelter for site personnel, and a telephone. The contractor provided additional equipment necessary for the completion of the installation and debugged the monitor installation.

NAFEC provided the two target aircraft and aircrews for this effort during the NAFEC flight tests. The only modification to the aircraft was the minor addition of an ATC radar beacon system omni aircraft antenna (TRU-1/2) in the nose (inside the radome) of the N-377 aircraft (figure 23) and the interconnection of coaxial cable to the aircraft's beacon transponder, all in place of the plane's antenna.

The nose of N-377 functioned as the phototheodolite facilities tracking point (figure 24). This aircraft's course deviation indicator was replaced by a microammeter-scaled indicator. The indicator was clamped to the pilot's steering yoke during the test flights. The other aircraft, N-9093P, was tracked at the midpoint between its wingtip landing lights from 7.0 nmi to approximately 1.6 nmi (12.9640 kilometers to 2.96 kilometers) along the flightpath. Between approximately 1.6 nmi (2.96 kilometers) and runway threshold, the aircraft's nose wheel was the tracking point (figure 24). Both aircraft used the 4096 code radar/beacon system. They flew the NAFEC runway 13 final approach path to the runway's threshold (figure 25). The test flights were flown in time periods varying between 2 and 4 hours. Due to the glide slope monitor subsystem being installed in the open field and the phototheodolite optical tracking system (figure 26), the test flights were flown in visual flight rules (VFR) weather.

The glide slope monitor subsystem was accurately time correlated to NAFEC range time to the hundredth of a second and recorded in binary coded decimal (BCD) format on the punched paper tape. The recorded time for each scan was the time of the first received reply of the scan. This time was slightly adjusted in the thousandths of a second in the data reduction, depending on the number of good replies that statistically determined the angular value of the glide slope monitor's scan measurement.

FLIGHT TESTS.

The planned flight tests (table 1) were being carried out from December 20, 1974, through February 20, 1975 (table 2). During February 1975 data reduction for the first two flight dates (December 20, 1974, and January 10, 1975) was accomplished. On the first flight date, the glide slope monitor subsystem mean error was approximately -0.2°. On the second flight date, the mean error was approximately +0.1°. Thus, a varying bias was seen in the monitor subsystem which was considered unacceptable and the flight tests were discontinued.

The reduced data were shown to the contractor in February 1975, and this resulted in an onsite test and analysis of the monitor subsystem which was completed in August 1975. The contractor concluded that the monitor subsystem probably needs an improved receiver beacon defruiting and filtering equipment.

NAFEC, in conjunction with SRDS, terminated the testing effort at this point, thus cancelling the balance of the planned flights. SRDS then directed NAFEC to complete the evaluation based on the previously collected data and to document the evaluation with a final report.

DATA COLLECTION.

The glide slope monitor subsystem digitally records its receiver output data on punched paper tape. The punched tape format is shown in figure 27. The contractor developed and implemented this format with minor modifications suggested by NAFEC based on its testing experience.

The phototheodolite facility digitally records on magnetic computer tape the elevation and azimuth tracking angles every 0.5 seconds from each of the three inuse of the four tracking towers, along with NAFEC range time. A real-time solution is printed out and plotted of the test target's flightpath to confirm the aircraft's action during the test. The real-time printout offers Cartesian track data every second, referenced to the test's theoretical touchdown point on the runway 13 centerline. The real-time plot offered a three-dimensional trace (x-y and y-z) of the test aircraft's flightpath. Photographic data were taken as backup data, but not used.

An ATC specialist assisted the test operations by coordinating the test with approach control in the NAFEC Airport Tower and by observing the actual flight test environment on the ASR-4 maintenance monitor in the equipment room of the airport tower. The test area was defined by extending the runway 4/22 centerline from its intersection with the runway 13/31 centerline in both directions for 10 nmi. Extending this 10 nmi (18.5 kilometers) radius in the direction of the runway 13 final approach path by a full 180° rotation set the test area layout. The NAFEC ATC Tower controlled altitude from zero to 5,000 feet (1524 meters).

The ATC specialist could then observe all ASR-4-detected targets in the test area as well as the designated test target. During the tests, nontest beacon replying aircraft were identified. Through the ATC tower personnel, those

TABLE 1. GLIDE SLOPE MONITOR SUBSYSTEM PLANNED FLIGHT TESTS

ROUTES	FLIGHTS (QUANTITY) N-377
ILS 3.0° Glide Slope	30
1.8° Right of ILS 3.0° Glide Slope	5
1.8° Left of ILS 3.0° Glide Slope	5
0.35° Below ILS 3.0° Glide Slope	5
0.35° Above ILS 3.0° Glide Slope	5
1.8° Right 0.35° Below ILS 3.0° Glide Slope	5
1.8° Left 0.35° Below ILS 3.0° Glide Slope	5
1.8° Right 0.35° Above ILS 3.0° Glide Slope	5
1.8° Left 0.35° Above ILS 3.0° Glide Slope	5
Level Flight at Middle-Marker Altitude	5
Level Flight at Outer Marker Altitude	5

Flight Trips - 80 Est. Hours/Trip - 0.20 Est. Flight Hours - 26.40

TABLE 2. GLIDE SLOPE MONITOR SUBSYSTEM ACTUAL FLIGHT TESTS

ROUTES	FLIGHTS (QUANTITY)	
	N-377	N9093P
ILS 3.0° Glide Slope	39	47
0.35° Below ILS 3.0° Glide Slope	5	0
Level Flight at Outer Marker Altitude	8	0
Level Flight at Middle Marker Altitude	7	0

Actual Flight Hours: N-377 - 15 N-9093P - 11

targets in the test area were requested to stop their beacon replies (as air traffic conditions permitted). The glide slope monitor subsystem test personnel were momentarily and continually notified by the ATC specialist during the tests of the presence and status of nontest, beacon replying aircraft.

The test aircraft, phototheodolite facility, ATC specialist and glide slope monitor subsystem during the tests were all in two-way very high frequency (VHF) communications with each other on NAFEC test frequencies. These frequencies were assigned with the test aircraft for the test period. The ground-based test personnel used the NAFEC phone system for backup communications.

DATA REDUCTION.

The contractor provided the discriminator characteristics (table 3 and figure 28) of the monopulse antenna. They were computed by the contractor from the antenna's measurements made on the contractor's antenna range.

The glide slope monitor subsystem's recorded data on punched paper tape were converted to computer magnetic tape on a General Automation Mini-Computer System (model SPC-16/45). The entire flight period's data were placed on one computer magnetic tape. These recorded data were separated flight-by-flight in an IBM 7090 computer system. Each flight's data were separated scan-by-scan where there were approximately 15 scans per minute (ASR-4 antenna revolves at 15.5 r/min). The number of beacon replies per scan varied from 10 to 90, and these replies had to be reduced to one reply (one angle of deviation per scan). The contractor suggested using the following technique that was, in minor ways, modified accordingly by NAFEC through its increasing experience in reducing this type of data. The contractor agreed to the minor modifications of the technique.

In this technique, the scan of replies comprised a maximum of 16 replies for a total duration of not more than 47 milliseconds (ms). During this time, an aircraft flying on the final approach path at 150 knots (67 meters per second) would traverse approximately 12 feet (3.658 meters) in range and 0.5 feet (0.152 meters) in altitude. These changes were small enough so that the average values of the measurements made on all replies of the scan provided a good measurement characterization for the scan, such that none of these measurements were interference corrupted.

In order to handle the interference corruption, the bad replies must be rejected prior to forming the averages. This rejection is based on the deviation that an interference-corrupted angle measurement reply has from the majority of the angle measurement replies in the scan. Originally, at least 10 unrejected measurements must have remained to generate angular output data. This figure of 10 valid replies was changed to 25 percent of the number of track mode scan replies after the search mode replies were automatically rejected. This provided a sufficient number of output data, scan-by-scan, for the flight. Then the median measurement (or each of the two closest in value to it in the case of an even number of measurements) must be one of those that remain. The median value was therefore used as a standard against which the bad measurements were rejected. The median, itself, may deviate from the majority of good measurements by the normal measurement tolerance for uncorrupted measurements.

TABLE 3. GLIDE SLOPE MONITOR SUBSYSTEM ANTENNA DISCRIMINATOR MEASURED CHARACTERISTICS

Relative to Boresight Elevation Angle (Space Degrees)	Measured Receiver Output Electrical Phase Angle (Electrical Degrees)*
-2.97	+144.6+ø
-2.64	+135.7+ø
-2.31	+126.7+ø
-1.97	+117.3+ø
-1.65	+105.7+ø
-1.32	+ 92.0+ø
-0.99	+ 74.4+ø
-0.66	+ 53.7+ø
-0.33	+ 26.7+ø
+0.05	- 5.8+ø
+0.38	- 36.5+ø
+0 71	- 63.3+ø
+1.04	- 87.4+ø
+1.37	-106.3+ø
+1.70	-121.9+ø
+2.03	-134.8+ø
+2.36	-144.9+ø
+2.69	-153.9+ø
+3.02	-162.8+ø

* ø is the receiver phase output for an input having zero difference component such that ø is nominally 180°.

Therefore, the initial rejection criterion was taken as a deviation of more than twice the maximum measurement error as follows:

Median $\leq 1°$, use test value of 0.0325°
Median $< 1°$, use test value of 0.065°.

Another refinement in the rejection process was executed on the unrejected measurements by rejecting any which deviated excessively from the mean of the remaining replies. Let the angle measurements remaining after the above median rejection test was made be the N quantities a_1, a_2, ..., and, with a mean m_N.

$$m_N = \frac{1}{N} \sum_{N=1}^{N} a_N$$

Test each of the N measurements by determining the quantities $C_k = (m_N - a_k)$ where $k = 1, 2, ..., N$.

It is assumed that only one of the N measurements is interference corrupted. Thus, an appropriate criterion is that $C_k \leq \frac{N-1}{N}$ times the expected maximum random error for uncorrupted measurements.

Mean $\leq 1°$, use test value of 0.0163°
Mean $< 1°$, use test value of 0.0325°.

Characterization of the angle information in a scan was the statistical average of the remaining replies after the search mode criteria and the above two tests were applied. The total number of replies and the unrejected balance were continually noted in the reduced data printout.

NAFEC surveyed the glide slope monitor subsystem antenna, after its installation, to determine the antenna's relationships with the NAFEC grid system. This information was necessary, due to the requirement of coorientation of the phototheodolite facility track data with the glide slope monitor antenna's zero-phase-angle point and axes. The antenna zero-phase-angle point is:

X = 112,302.776 feet (34231.00915 meter)
Y = 113,591.996 feet (34623.97630 meter)
Z = 10,085.574 feet (3074.18381 meter).

The antenna rotation down runway 13 (y, z axes) is 3 degrees, 00.0 minute, 00.0 seconds (3.0°). The antenna rotation toward the runway 13 centerline is (x, z axes) 1 degree, 45 minutes, 11.0 seconds (1.75305556°).

The average antenna-face rotation (at the zero-phase-angle point) about the z axis in a counterclockwise direction is 1 degree, 52 minutes, 16.6 seconds (1.87127778°).

An additional survey point, located the theoretical touchdown point (TD) on the runway 13 centerline at:

X = 111,816.186 feet (34082.69165 meter)
Y = 113,697.418 feet (34656.14046 meter)
Z = 10,072.987 feet (3070.34717 meter)

The TD point was dependent on where the ILS category III glide scope antenna's radiated cone meets the ground surface. This point was necessary to properly orient the phototheodolite facility's real-time data and plots.

The phototheodolite facility's recorded data (azimuth and elevation angles from three tracking towers plus NAFEC range time) was offline processed in an IBM 7090 computer system. It developed the three tower tracking solution for the test aircraft in Cartesian and spherical coordinates. These data were translated to a reference point in the NAFEC grid (the monopulse antenna zero-phase-angle point). The data were then rotated into the boresight line of the monitor antenna (x-z axes). This part of the computer programming has been operational, at NAFEC, since 1964. An additional rotation was made to this computer program (x-y axes). No y-z axes rotation was necessary, due to the monitor data having the boresight angle added to it.

The monitor and theodolite data were merged in the IBM 7090 computer system, where the two-flightpath aircraft tracks were compared and the difference data in terms of elevation angle degrees and altitude feet were generated. Besides the merged data computer printout, there was a summary merged data computer printout. Plots were made on a digital Calcomp plotter (model UNT-7000) of the track data and difference data (both in elevation angle degrees and in altitude feet). Samples of the individual flight data plots are shown in appendix A.

DATA ANALYSIS.

The mean error and two-sigma error variations in both angle (degrees) and altitude (feet) for each aircraft along each flightpath route, so as to contain an adequate number of data points, were statistically developed by route bins which were set at 0.166666 nmi (0.30866543 kilometer) width along the flightpath routes. The means, and two-sigma plot indicators, were arbitrarily located at the center of each data bin. If the values of the means or either of the two-sigma values equalled or exceeded the vertical axis limits, the mean or two-sigma plot indicators were shown at the respective axis limits. Just above the horizontal slant range axis, the number of data points in each bin were listed. The slant range axis on the plots originated (0.0 nmi) on the runway centerline at a point parallel to the zero-phase center of the monopulse monitor antenna. The contractual design goal measurement accuracy of 0.023° (10 times more accurate than the ILS glide slope accuracy) was shown on the error plots by dashed lines centered about the monitor antenna's boresight in terms of degrees or feet accordingly.

The error data were reviewed and those error data that exceeded 1° in magnitude when beacon-replying, known nontest aircraft were flying in the test area, were deleted from the data set. Other error data, less than 1 percent of the total data, that exceeded 1° in magnitude, were also deleted from the data set. The assumption was that these error data were caused by beacon replying from unknown nontest aircraft, either flying above the local ATC controlled altitude in the test area or in the test area, and beacon replying on a code not used by local ATC. The remaining error data which were all ≤ 1° in magnitude were included in the test results.

RESULTS

TEST RESULT.

Plots of the statistical data are shown for each aircraft on each of the flight routes of each flight period. Figures 29 through 34 represent the statistical error data of the N-377 aircraft flying on the 3° glide slope flightpath for each flight period. Figures 35 through 42 represent the statistical error data of the N-9093P aircraft flying on the 3° glide slope flightpath for each period. Each flight period/route has its own distinctive error, most of which are negative (where the phototheodolite measurement system indicated the target aircraft was at a higher altitude than that indicated by the WE Co. measurement system). It should be noted that for the entire January 10, 1975, flight period, the error was positive.

Statistical groupings were made to include all flight period data on each route for each aircraft. Figures 43 and 44 represent the statistical error data of the N-377 aircraft flying on the 3° glide slope flightpath for all such flight periods. Figures 45 and 46 represent the statistical error data of the N9093P aircraft flying on the 3° glide slope flightpath for all such flight periods. Figures 47 and 48 represent the statistical error data of the N-377 aircraft flying the -0.35° below the 3° glide slope flightpath. Figures 49 and 50 represent the statistical error data of the N-377 aircraft flying at a level 1,508 feet (459.654 meter) altitude along the 3° glide slope flightpath intersecting the glide slope at the OM. No group statistics were developed for the 230 feet (70.106 meter) altitude-level flightpath, since only two of the seven flights resulted in collected data.

The statistical error data on the test result plots do not fall within design goal tolerance accuracy limits. The statistical error data group results vary according to the influences of the individual flight period's statistical error data biases.

Statistical error data were developed regardless of aircraft type (N-377 and N-9093P) or flight period for all 3° ILS glide slope flying, as shown in figures 51 and 52. This statistical grouping accounts for 76 flights of reducible data.

Statistical analysis of the error data by testing to determine that the variances are from the same population (F tests) and the means are from the same population (t tests) were accomplished. They are shown in appendix B. Within each flight period the error data from the earlier to later times were examined. Also, the error data from flight period to flight period for the same aircraft and route were examined. A special examination of the error data from different flight periods and different aircraft for the same flight route was accomplished.

EXPERIENCED PROBLEMS.

1. The electrical schematics and wire lists provided by the WE Co. on the glide slope monitor subsystem for the installation debugging period, and later in fixing the equipment failures, were found not to be completely correct. Many paperwork errors were uncovered in repairing the equipment. They were noted and the corrections were shown to WE Co. personnel.

2. A number of integrated circuit chips failed following the installation completion. They are listed in table 4.

TABLE 4. GLIDE SLOPE MONITOR SUBSYSTEM EQUIPMENT INTEGRATED CIRCUIT CHIP FAILURES.

Location in	Failed	Type	Card No.	Position No.	Failure Between Pins
Digital Bucket	SN-7404N	Hex Inverter	A-10	77	5/6
Digital Bucket	SN-7404N	Hex Inverter	A-12	18	3/4
Digital Bucket	SN-7404N	Hex Inverter	A-05	[illegible]	12/13
Digital Bucket	SN-7404N	Hex Inverter	A-05	97	1/2
Paper Tape Punch	SN-74L98	4 Bit Storage Register	Perfect Clock	27	---

3. WE Co. provided for the calibration of the glide slope monitor subsystem to determine if the monitor antenna's boresight angle had electronically changed by the time of a flight test period. The calibration procedure required test personnel to climb the monopulse antenna's I-beam support and, at the height of the hybrid coupler, disconnect the four semirigid coaxial cables from

the antenna. Then he had to connect four termination resistive loads to the hybrid coupler. This ensured only the calibration beacon transponder's replies being received. This procedure was accomplished only on the first and last flight test periods. During the other flight test periods, calibrations were accomplished by using a beacon reply "free" test area with the monopulse antenna connected to the hybrid coupler. The beacon free test area is fully defined and explained in the DATA COLLECTION portion of this report. This procedure was necessary due to the high wind and cold temperature experienced during each of these flight test periods. The calibrations from these flight test periods had significant offsets from the boresight angle achieved by the WE Co. procedures for calibration. These calibration's offset-from-boresight angles were rejected due to the antenna and, subsequently, the environment being in the system. It was originally assumed that the beacon reply "free" test area was equivalent to removing the antenna from the calibration of the receiver. However, due to the high number of beacon replies per ASR-4 scan (hits/scan) during the data collection calibrations, there may have been beacon-replying nontest aircraft using beacon codes not normally used within the data collection test area that would not show up on the local ATC radar-beacon displays. This is a realistic possibility, due the high number of hits/scan and the various indicated angles within a scan of data. Therefore, the assumption was not a correct one. The two usable calibrations were very close in value as their average was used in the data reduction for all flight test periods.

The ASR-4 was operated throughout the period of all the tests within its manufacturer's performance specifications, including the side lobe suppression (SLS) subsystem, as a commissioned facility of the Eastern Region. The operating conditions were checked daily at least once during each of two daily shifts of maintenance personnel. If out-of-operating-tolerances were experienced, they were noted in the facility log books. During the 3 activity tests, no out-of-operating-tolerance conditions were recorded in the ASR-4 facility's log books.

4. A large number of beacon replies (up to 90) were sometimes recorded for the test target per ASR-4 target scan. This maximally experienced number greatly exceeds the nominally expected number of 16 to 20 beacon replies for a single target (not including the effects of multipath). A limited investigation of the high beacon replies with the assistance of NAFEC beacon experts was executed. Static tests were accomplished using aircraft beacon transponders (TRU-1) situated in trucks with their omniantenna (TRU-1/2) on the trucks' mast.

The ASR-4 facility's near-field was investigated for the high number of beacon replies at that site which was approximately 4,500 feet (1371.645 meters) from the glide slope monitor subsystem. No unusual number of beacon replies were observed on an oscilloscope display. Approximately 16-20 beacon replies were observed on the oscilloscope display of the transponder output at the time of the test. The ASR-4 facilitity's far-field at the glide slope monitor subsystem site was similarly investigated with the same results.

During a full monitor subsystem calibration, the ASR-5 and the ASR-7 were requested to not transmit beacon interrogations. In doing this, there was no noticeable effect on the monitor's replies as to the number of replies per scan or to the deviation angle value of the received replies per scan.

5. An omnitype TRU-1/2 antenna was installed on a fixed tower in the monopulse antenna far-field. The TRU-1/2 antenna was connected during the tests via coaxial cable to a TRU-1 transponder system aboard a truck positioned at the tower's base. Basic electrical power for the transponder system was obtained from a distribution box at the tower's base.

The relative locations of the tower and the Glide Slope Monitor Subsystem are shown in figure 53. The TRU-1/2 antenna was installed 104 feet (31.70 meters) up on the tower the base of which was at a surface level of approximately 67 feet (20.4223 meters). The surface level was approximately equal to the monitor antenna's support base surface level.

The TRU-1/2 antenna was 1.34° below the monopulse antenna boresight. The azimuth sector gate of the monopulse antenna boresight swept the ASR-4 facility from 309° true to 014° true with the tower on the 359° true radial of the azimuth sector gate. During calibration tests of the entire monitor subsystem, the entire monitor test area was beacon reply free. The monitor subsystem performance during the calibration tests utilizing the tower/target is shown in table 5.

TABLE 5. GLIDE SLOPE MONITOR SUBSYSTEM FIXED TOWER/TARGET PERFORMANCE

Test Date	Test Period	Approx. Avg. Binary Counts per Scan Deviation from Boresight	Equivalent Space Degrees Below Monopulse Antenna Boresight
4-18-75	P.M.	-65	0.56
4-21-75	P.M.	-35	0.30
4-22-75	P.M.	-35	0.30
4-23-75	P.M.	-60	0.52
4-24-75	A.M	-65	0.56
4-25-75	A.M.	-35	0.30
4-29-75	A.M.	-35	0.30
5-5-75	P.M.	-35	0.30
5-7-75	P.M.	-25	0.21

CONCLUSIONS

1. The varying-biased mean-angular-deviation measurements from boresight and the high number of beacon replies per scan were due to multipath effects and/or the presence of the most minimal beacon defruiting technique in the glide slope monitor subsystem.

2. The glide slope monitor subsystem did not meet the contractural design goal specification of a statistical accuracy 10 times better (0.023°) than the ILS glide slope over any part of the final 6 nmi (11.112 kilometers) of the final approach path.

3. The glide slope monitor subsystem error measurements were not always reproducible. All the average mean error values for each of the flight test periods varied between approximately -0.3° and +0.1°. It should be noted that the two-sigma value for all flight test periods was typically ±0.13°, with a maximum of ±0.775° over the final 6 nmi (11.112 kilometers) of the final approach path.

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1. Proposal for Performance Monitor of Final Approach, Touchdown and Rollout, Part I (technical), Negotiation No. H-1334, Westinghouse Electric Company, June 30, 1971.

2. Frey, George W., Jr., Data Processing Subsystem Performance Specifications, Revisions A, B and C, pages 24 through 28, Purchase Order No. 86GJ-SB-53384-OS, Westinghouse Electric Company, November 22, 1972.

3. Basil, I. T., Final Approach Performance Monitor, Federal Aviation Administration, Final Report, FAA-RD-76-117, July 1976.

4. United States Flight Inspection Manual, FAA-Handbook OA-P-8200-1, May 1963.

5. ICAO Aeronautical Communications, Annex 10, Seventh edition, August 1963.

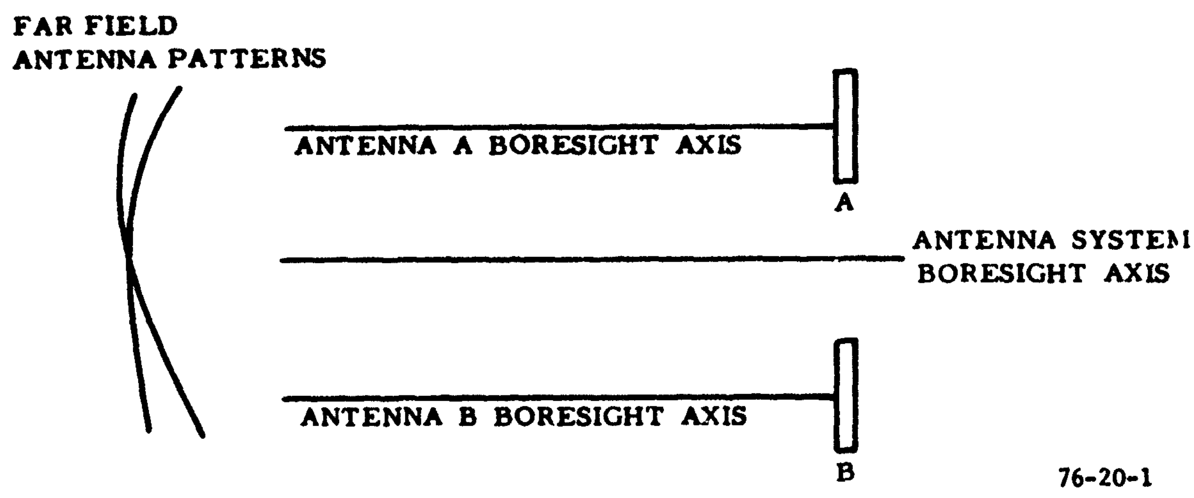

FIGURE 1. RELATIONSHIP OF SUBARRAYS FOR MONOPULSE ANTENNA MEASURING

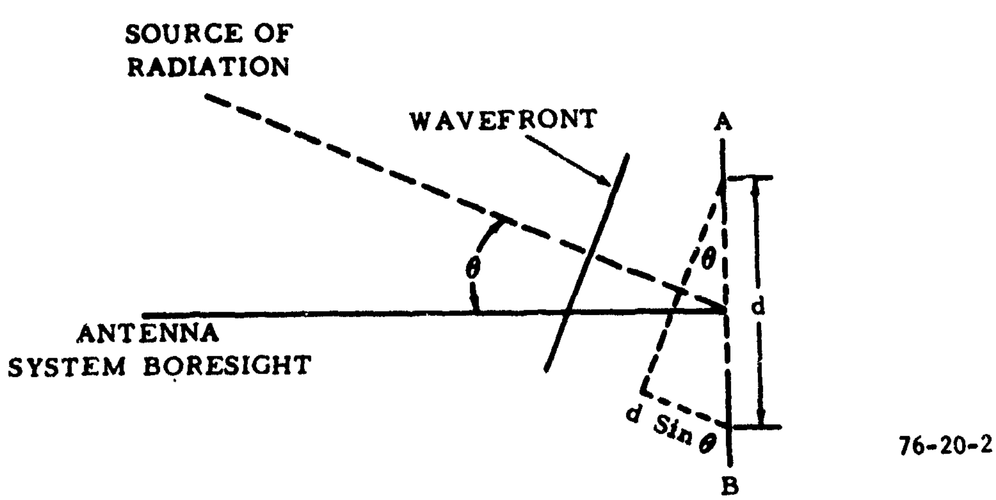

FIGURE 2. PHASE RELATIONSHIP OF WAVEFRONTS RECEIVED AT MONOPULSE ANTENNA

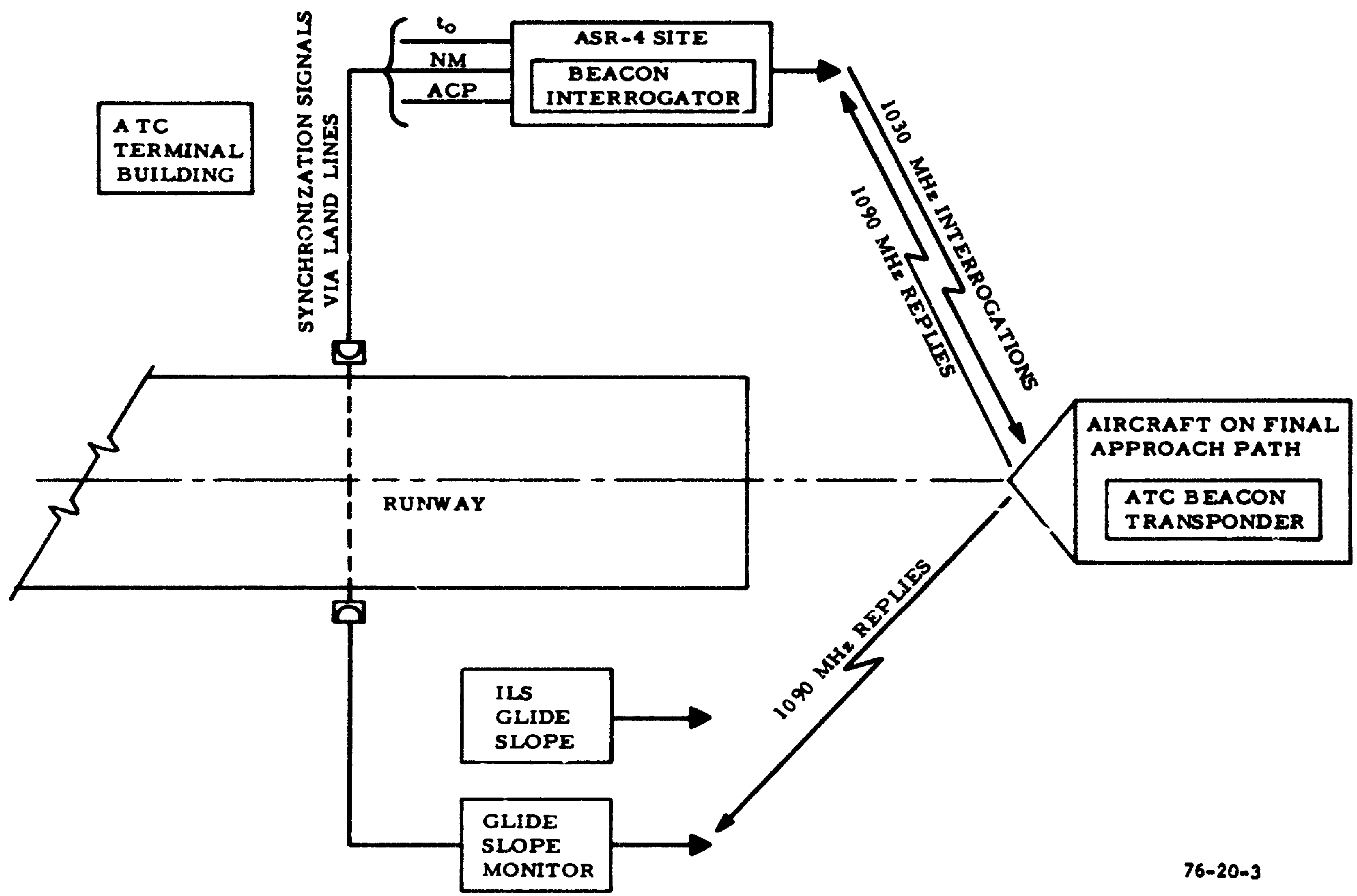

FIGURE 3. BASIC BLOCK DIAGRAM OF GLIDE SLOPE MONITOR SUBSYSTEM

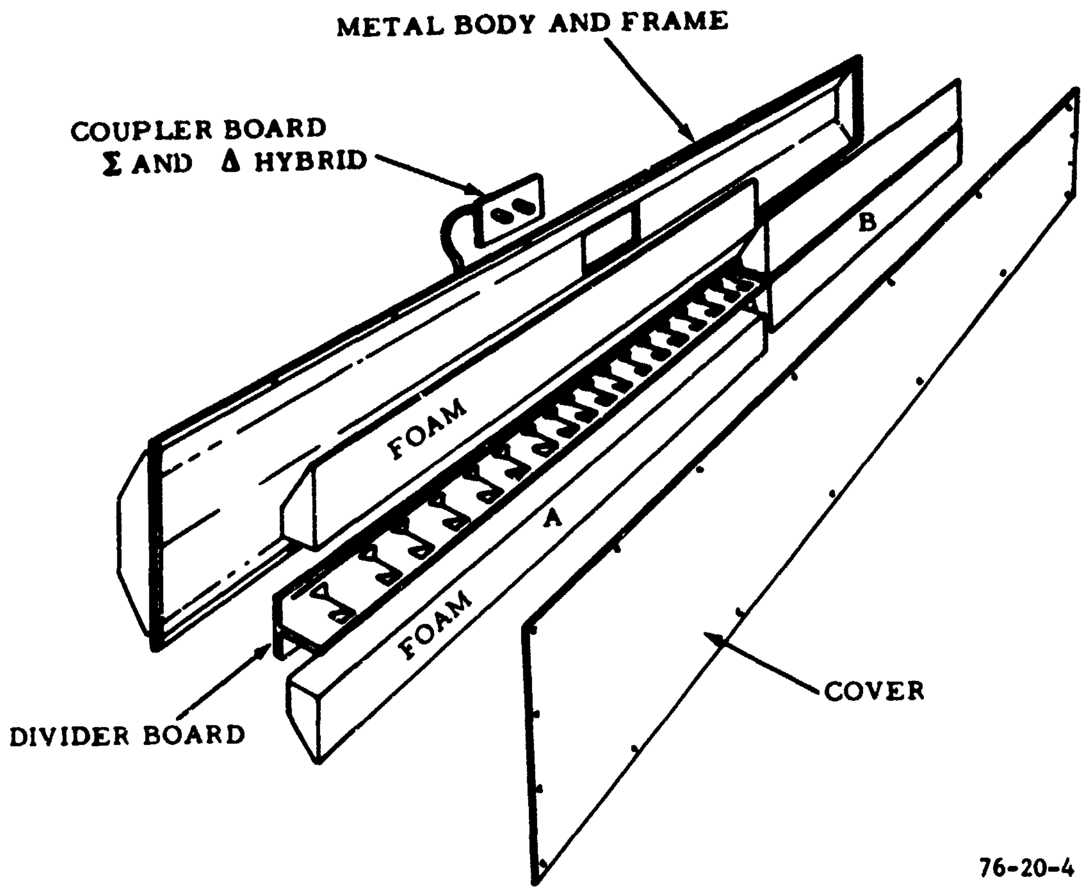

FIGURE 4. EXPLODED VIEW OF GLIDE SLOPE MONITOR MONOPULSE ANTENNA

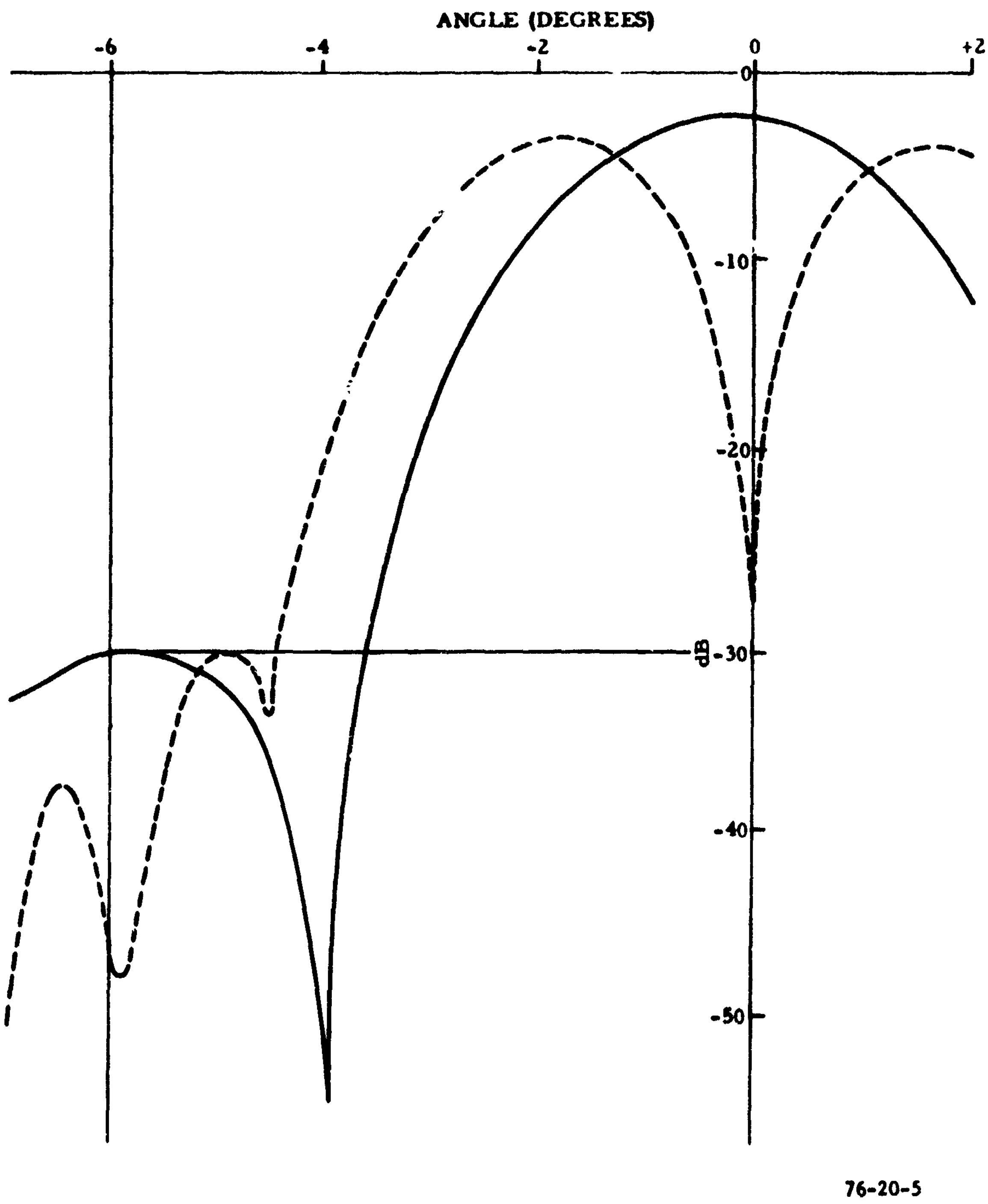

FIGURE 5. MONOPULSE ANTENNA RESPONSE PATTERN

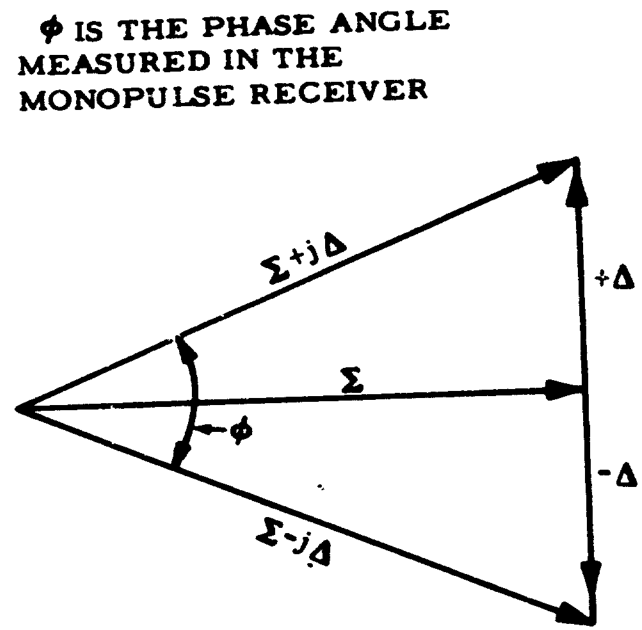

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FIGURE 6. VECTOR REPRESENTATION OF MONOPULSE RECEIVER PHASE MEASUREMENT

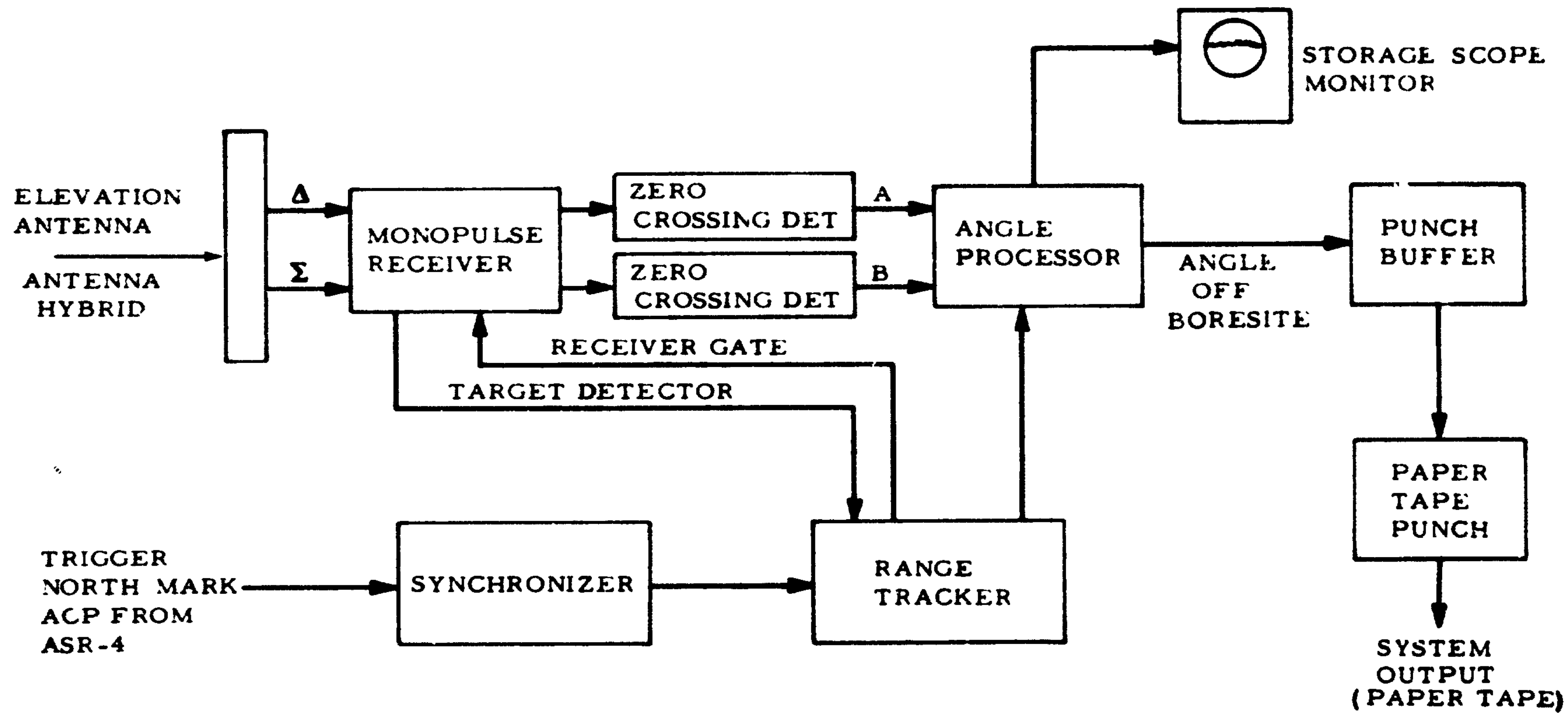


FIGURE 7. GLIDE SLOPE MONITOR RECEIVER EQUIPMENT BLOCK DIAGRAM

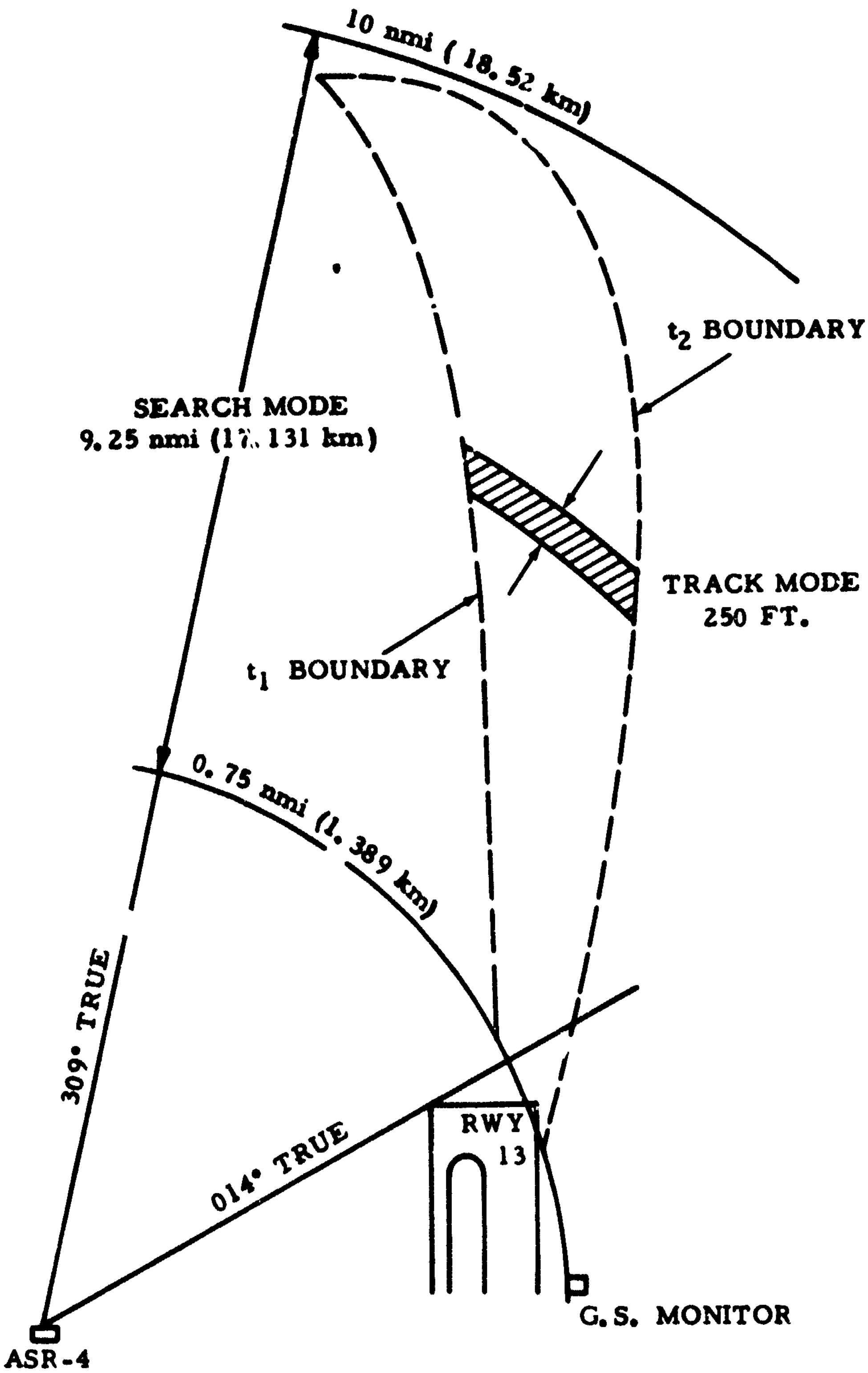


FIGURE 8. GLIDE SLOPE MONITOR SECTOR, RANGE AND TIME GATING

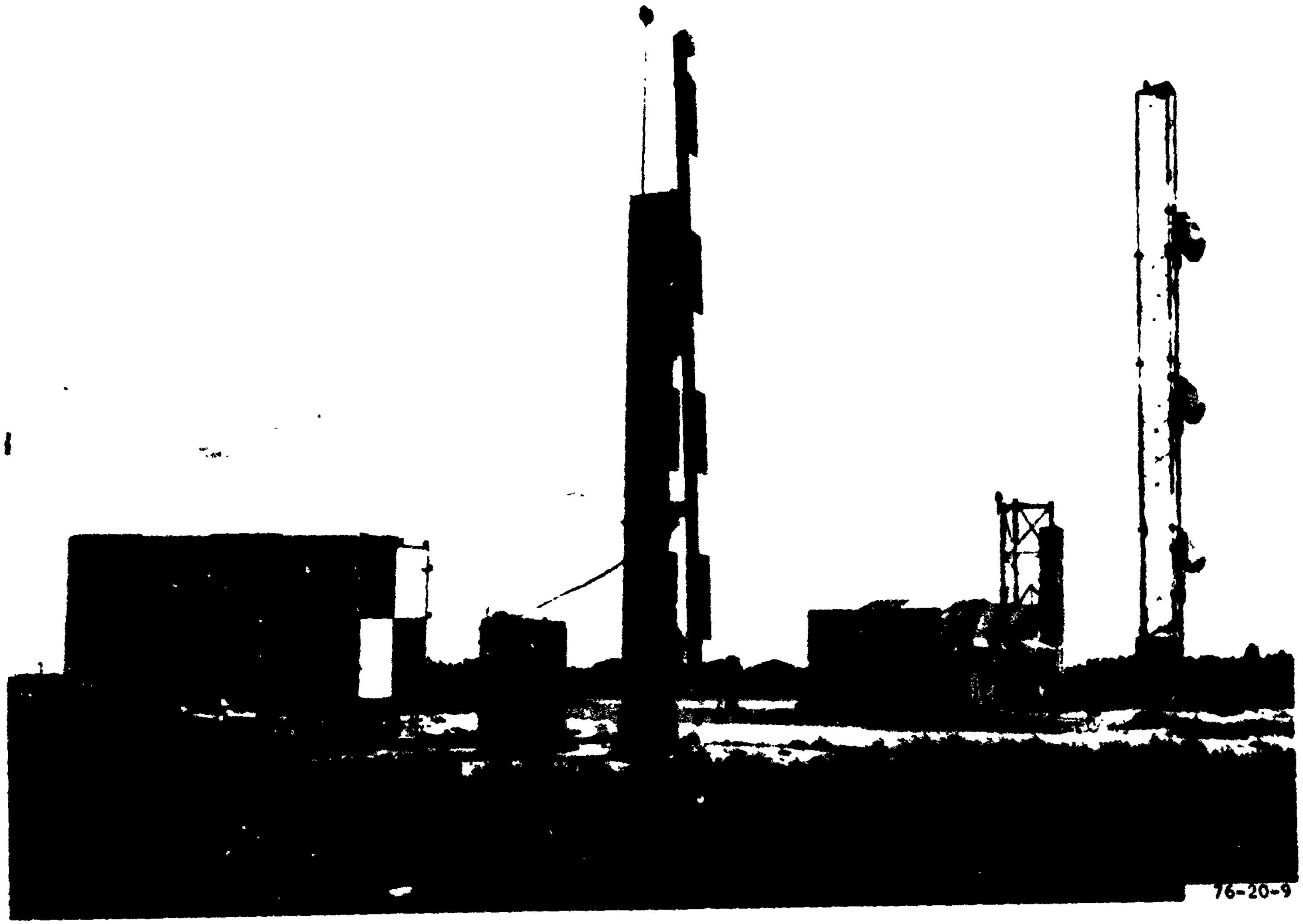


FIGURE 9. GLIDE SLOPE MONITOR SITE WITH COLLOCATED GLIDE SLOPE SUBSYSTEMS

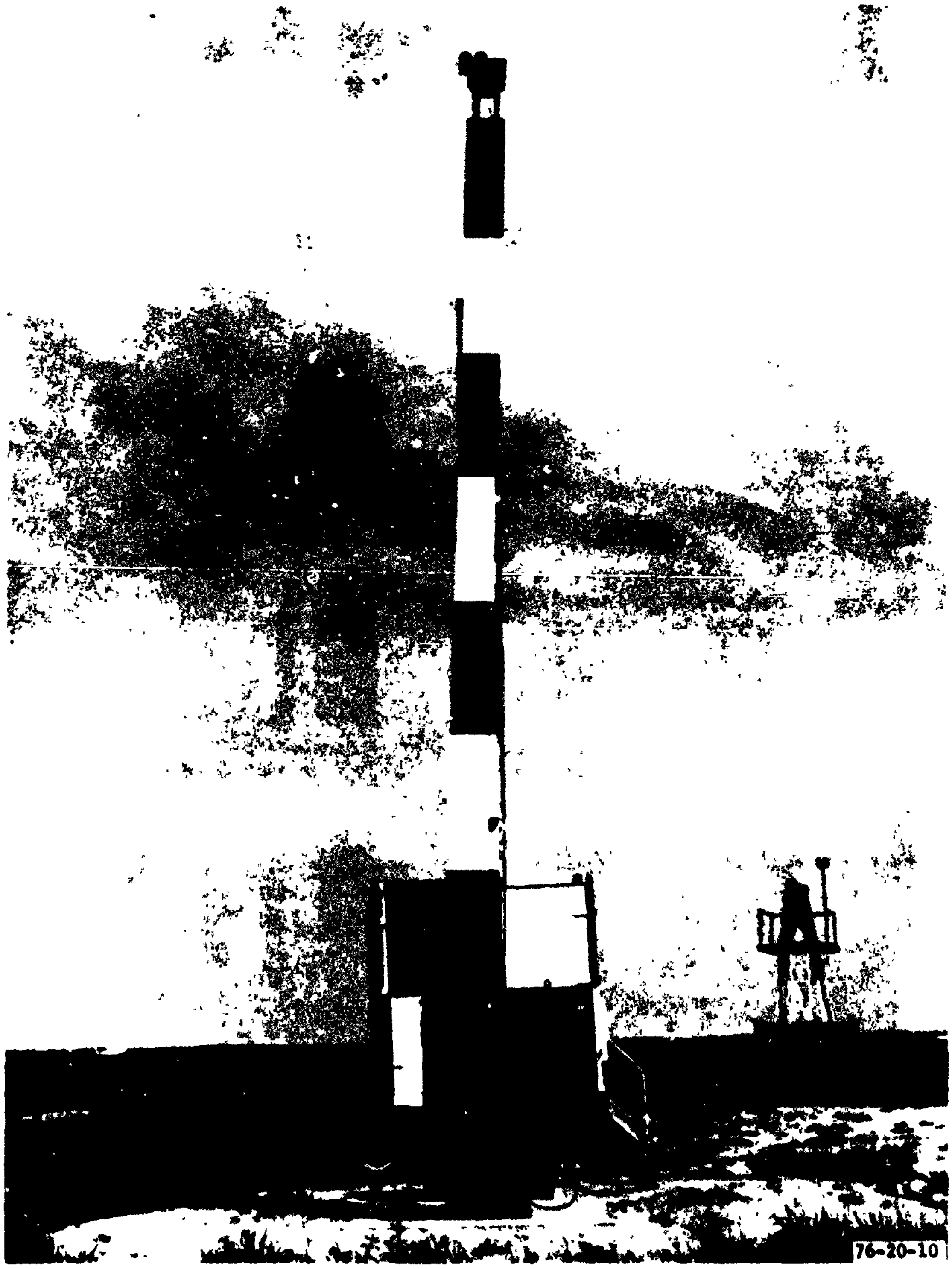


FIGURE 10. GLIDE SLOPE MONITOR MONOPULSE ANTENNA INDICATING 1°45"11.0" ROTATION TOWARDS RUNWAY 13

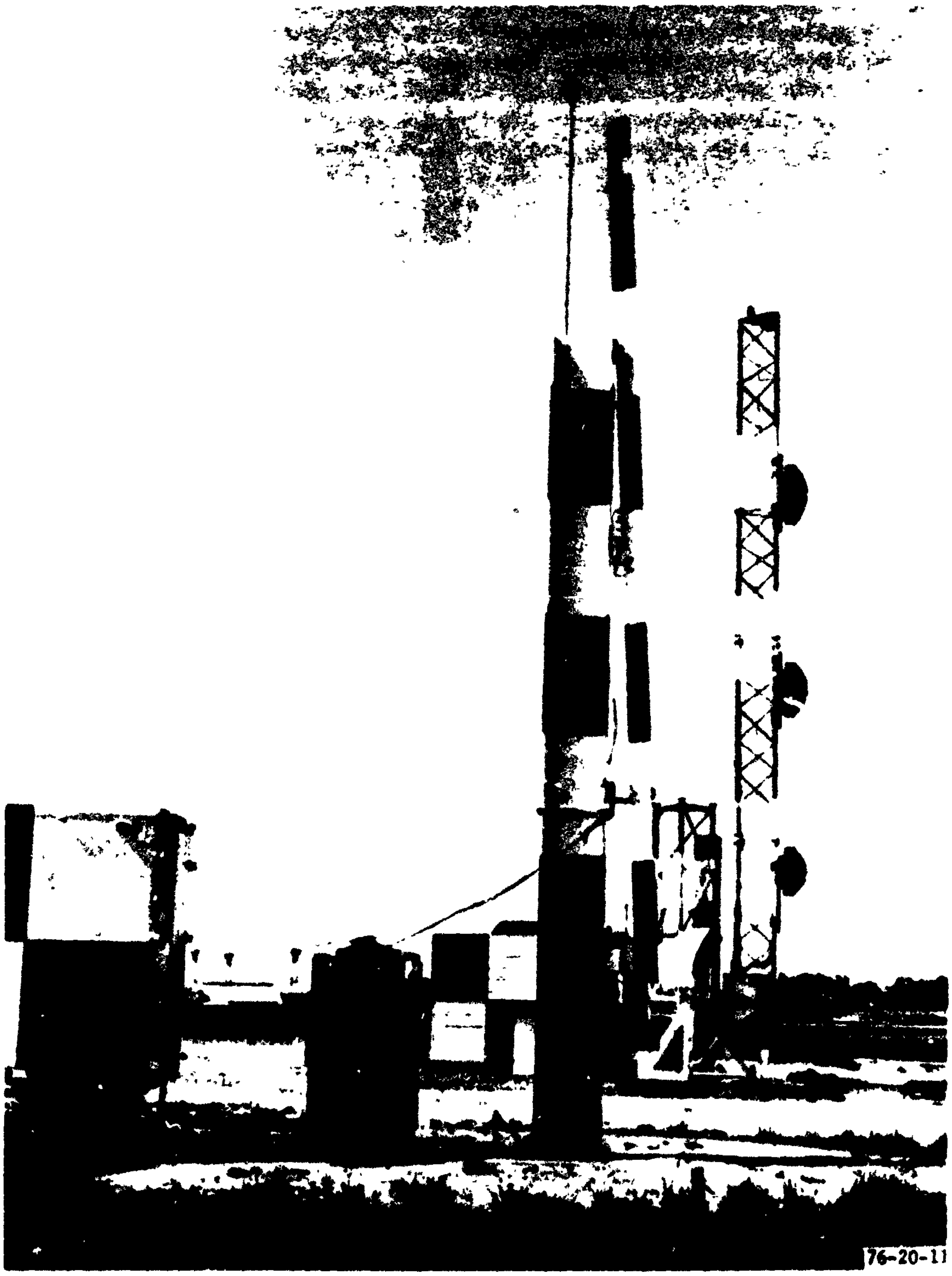


FIGURE 11. GLIDE SLOPE MONITOR MONOPULSE ANTENNA INDICATING 3°00'00.0" ROTATION

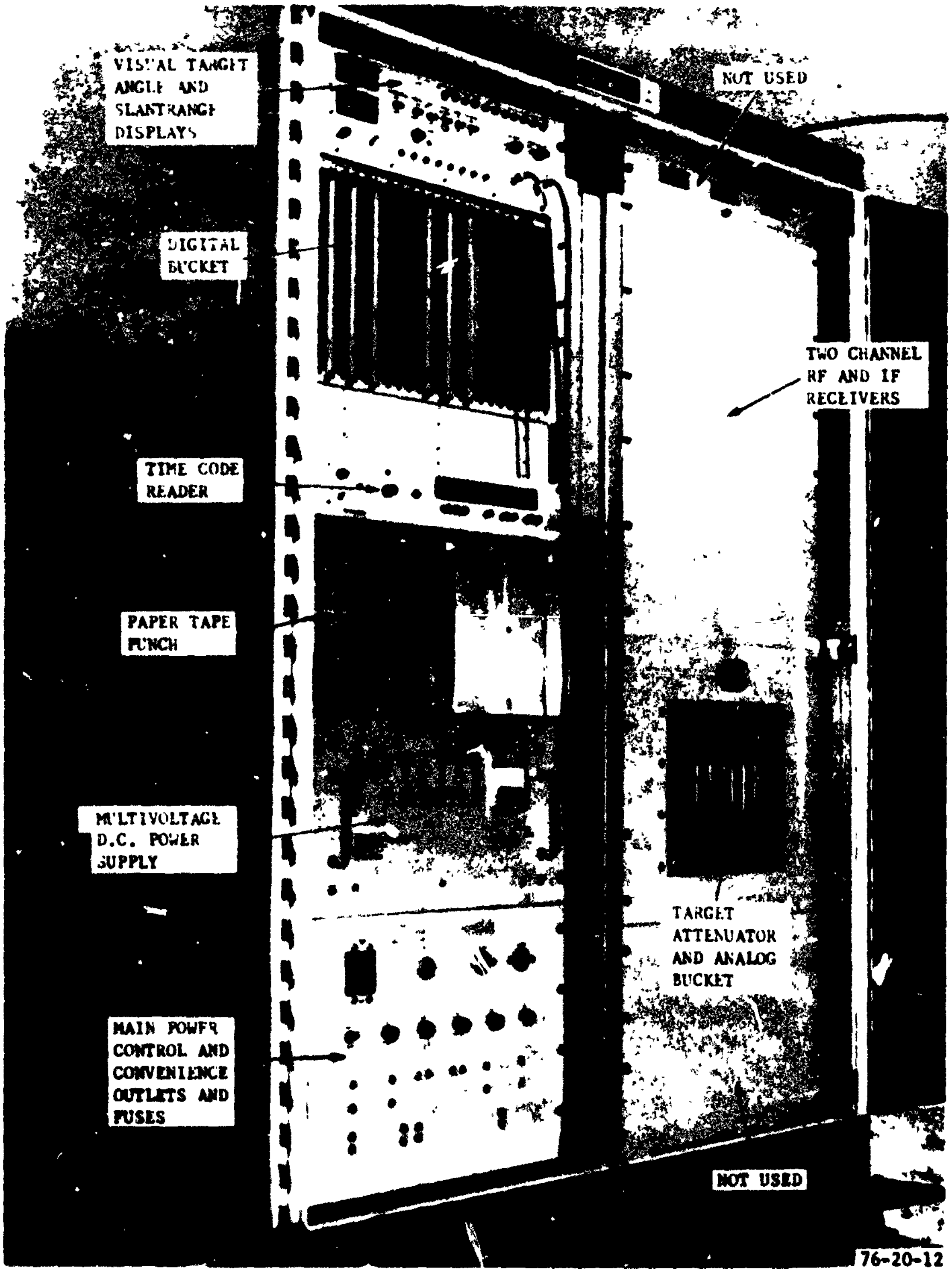


FIGURE 12. GLIDE SLOPE MONITOR RECEIVER CABINET, FRONT VIEW

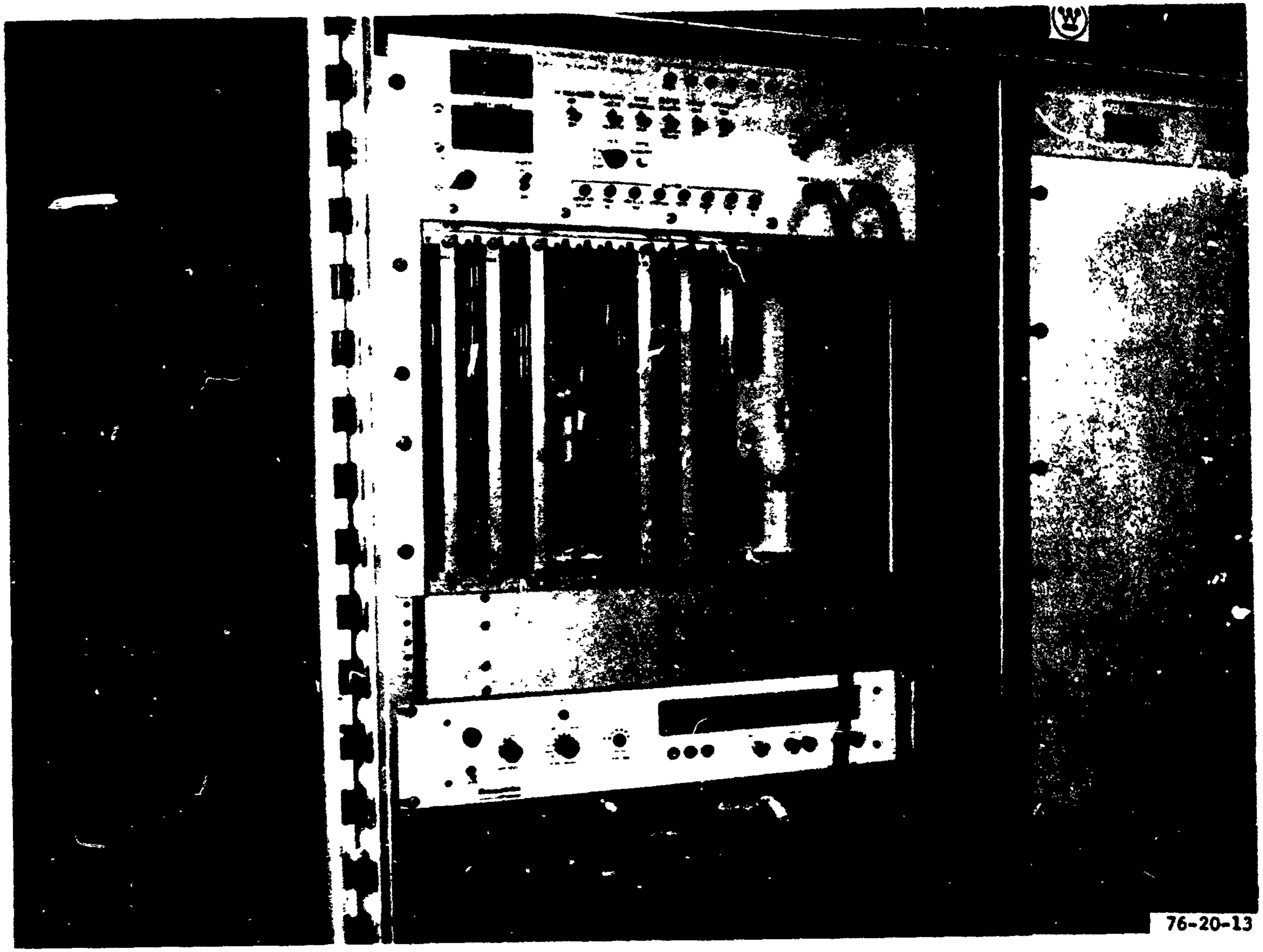


FIGURE 13. GLIDE SLOPE MONITOR RECEIVER CABINET, UPPER LEFT-HAND CLOSE-IN FRONT VIEW

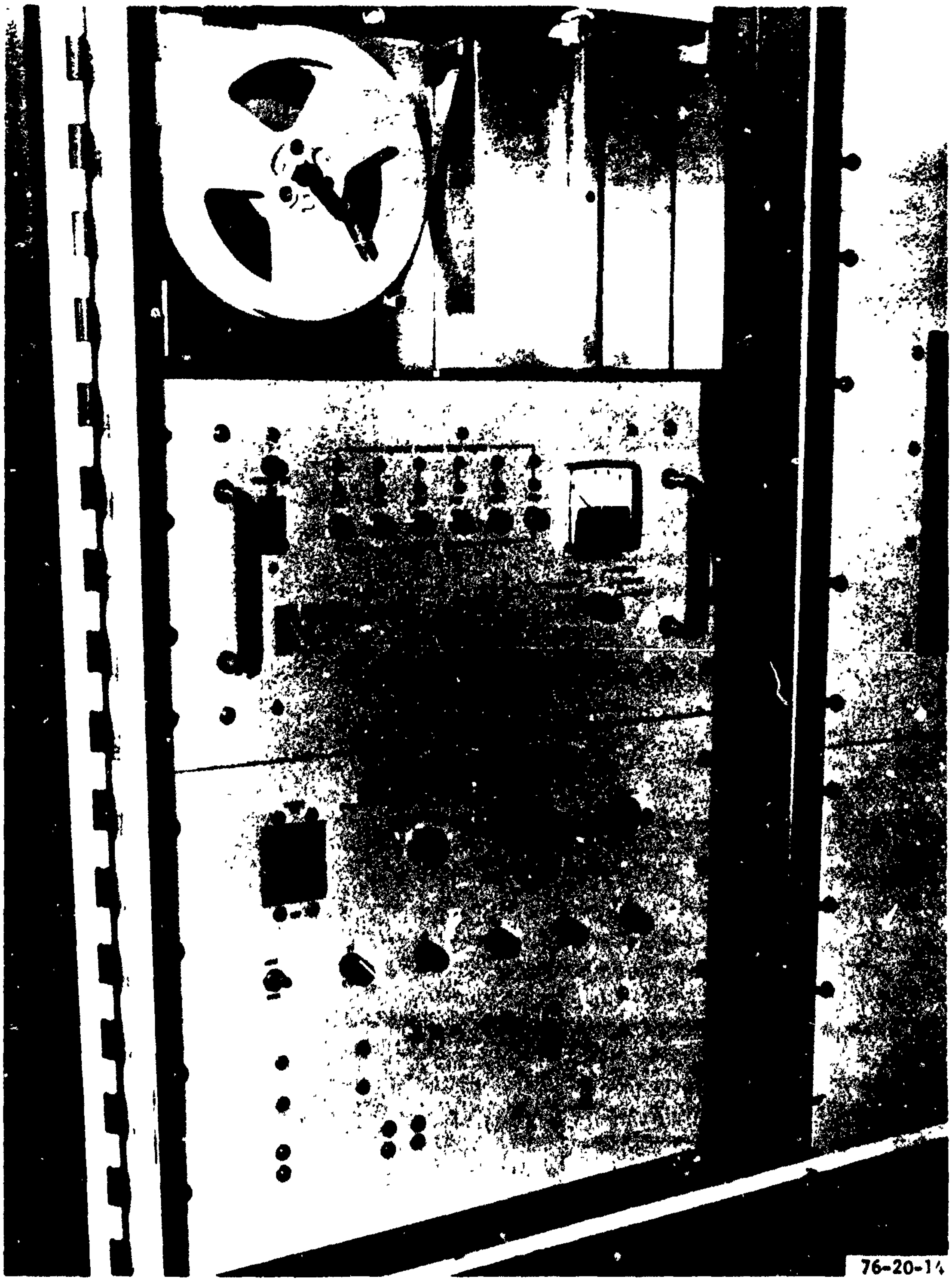


FIGURE 14. GLIDE SLOPE MONITOR RECEIVER CABINET, LOWER LEFT-HAND CLOSE-IN FRONT VIEW

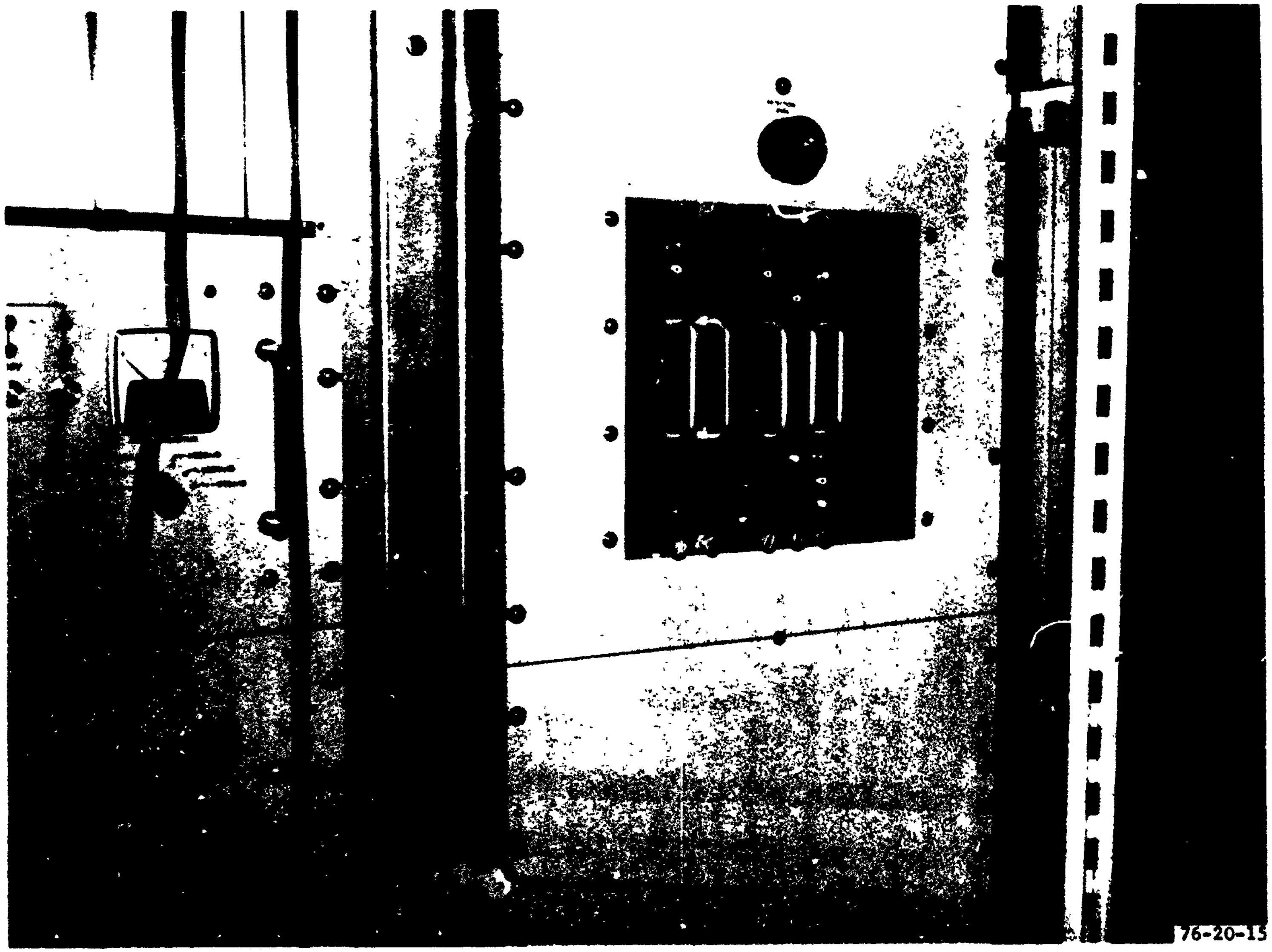


FIGURE 15. GLIDE SLOPE MONITOR RECEIVER CABINET, MIDDLE RIGHT-HAND FRONT VIEW

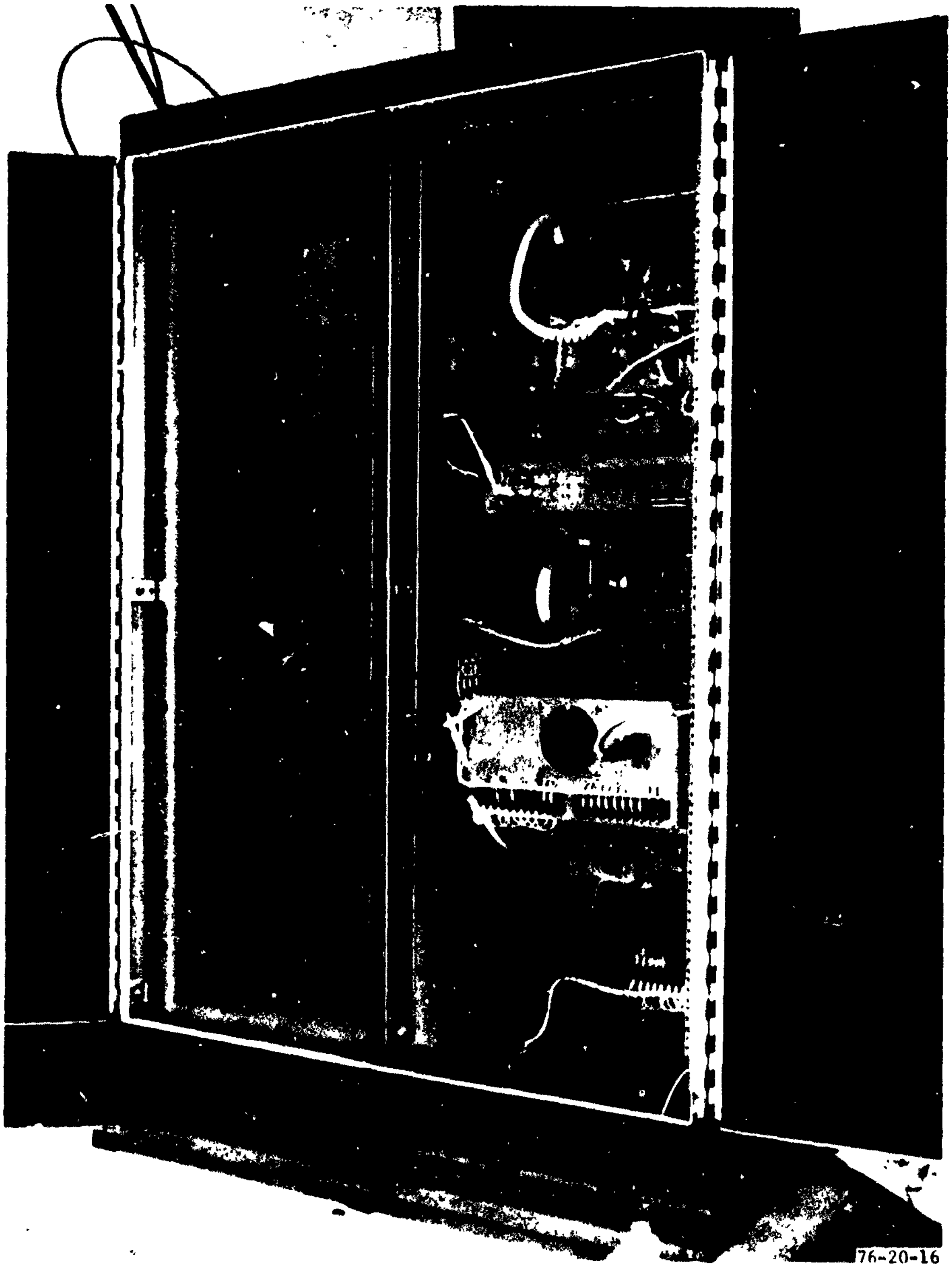


FIGURE 16. GLIDE SLOPE MONITOR RECEIVER CABINET, REAR VIEW

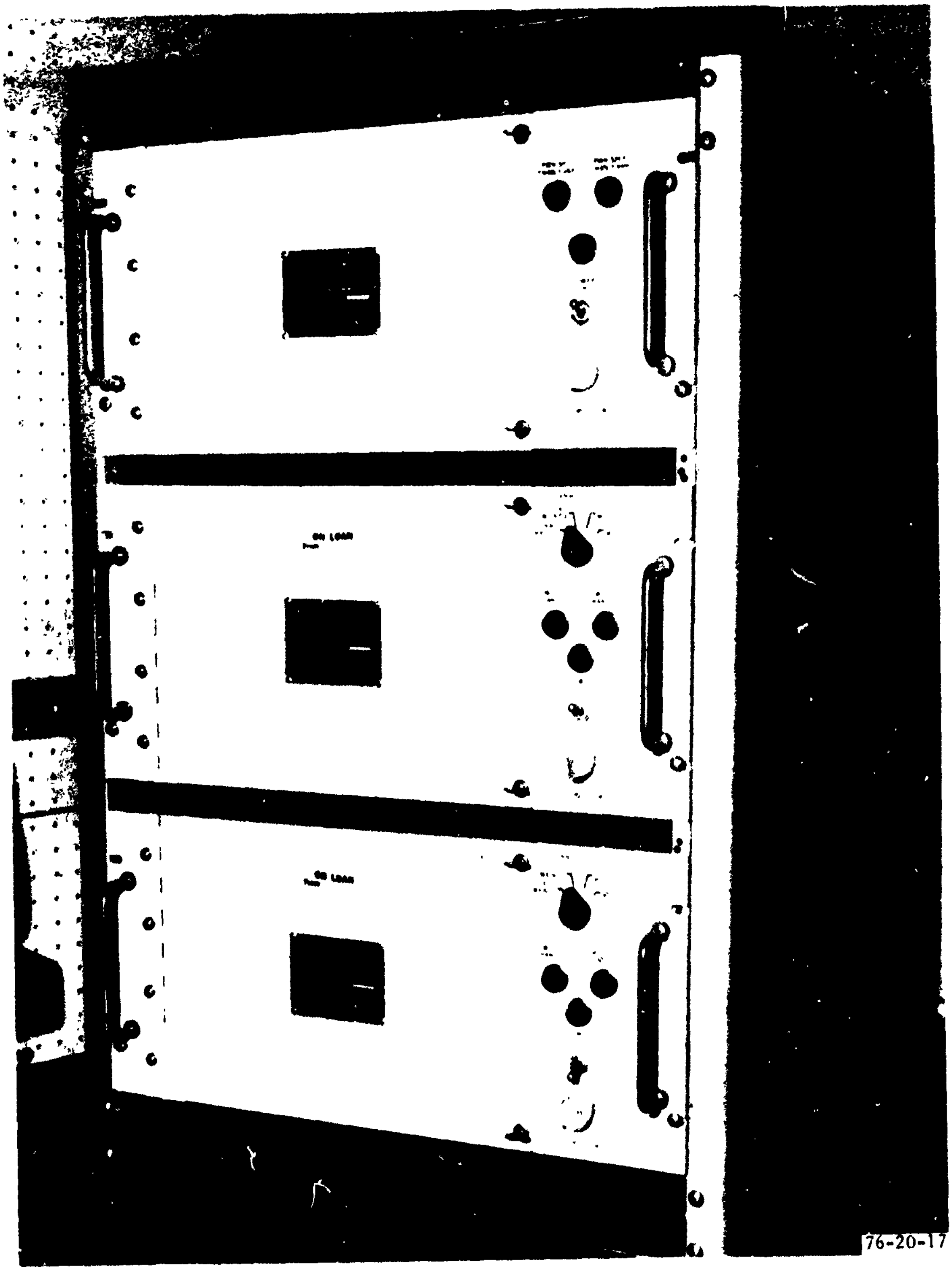


FIGURE 17. ASR-4 FACILITY BEACON PRETRIGGER SIGNAL CONDITIONING EQUIPMENT LOCATED IN THE TRAILER

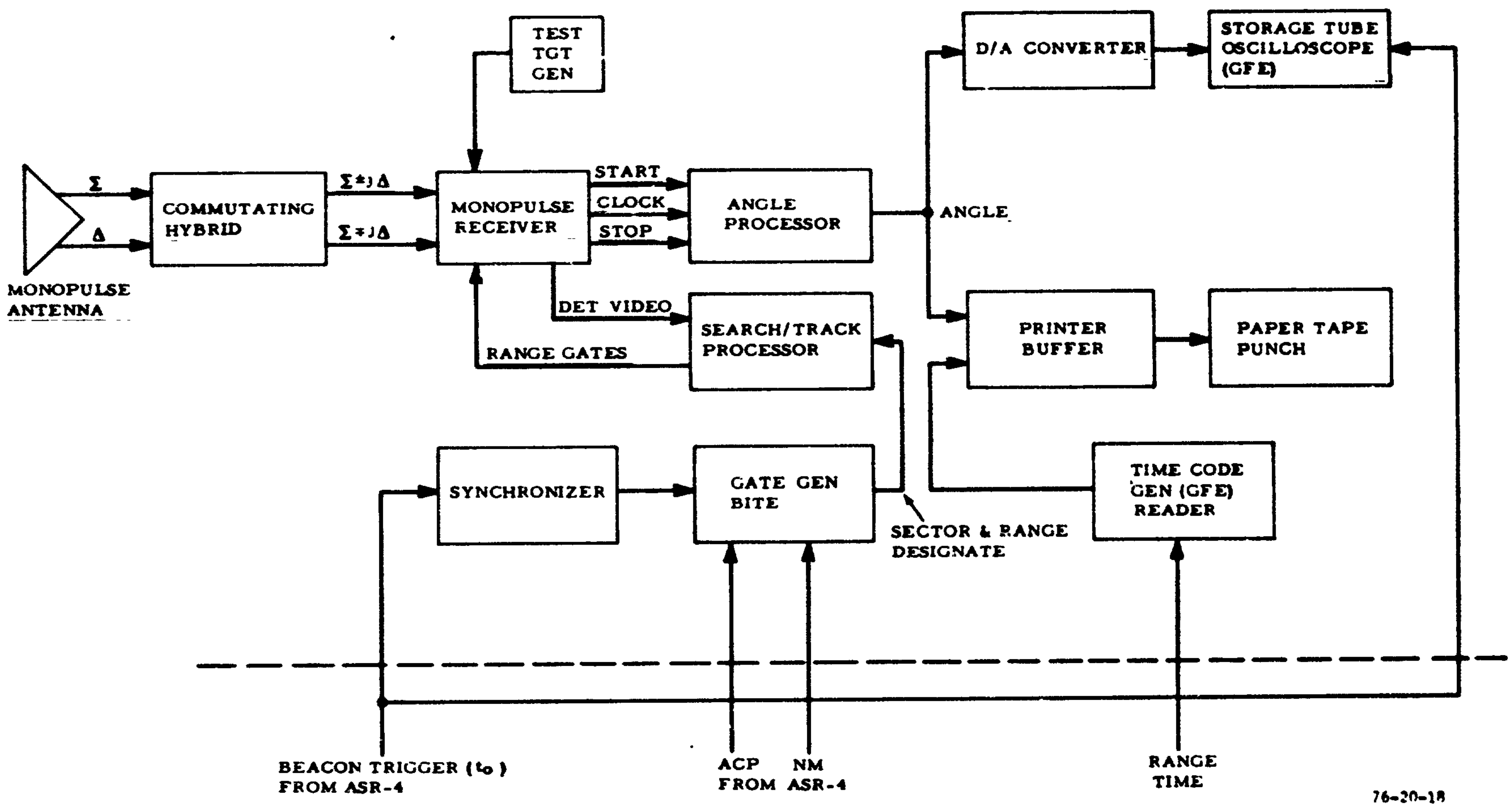


FIGURE 18. GLIDE SLOPE MONITOR RECEIVER SUBSYSTEM BLOCK DIAGRAM

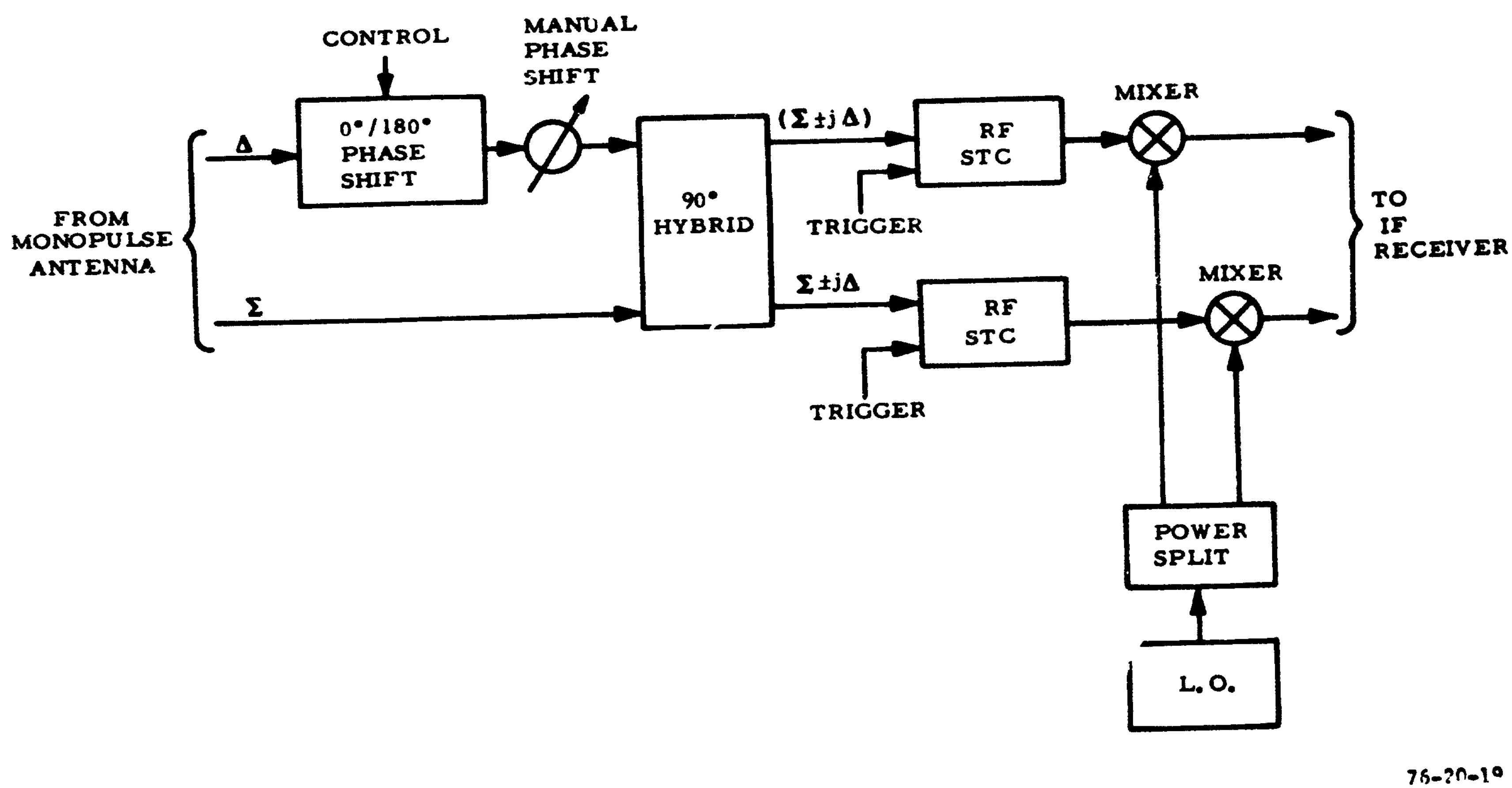


FIGURE 19. GLIDE SLOPE MONITOR RF RECEIVER BLOCK DIAGRAM

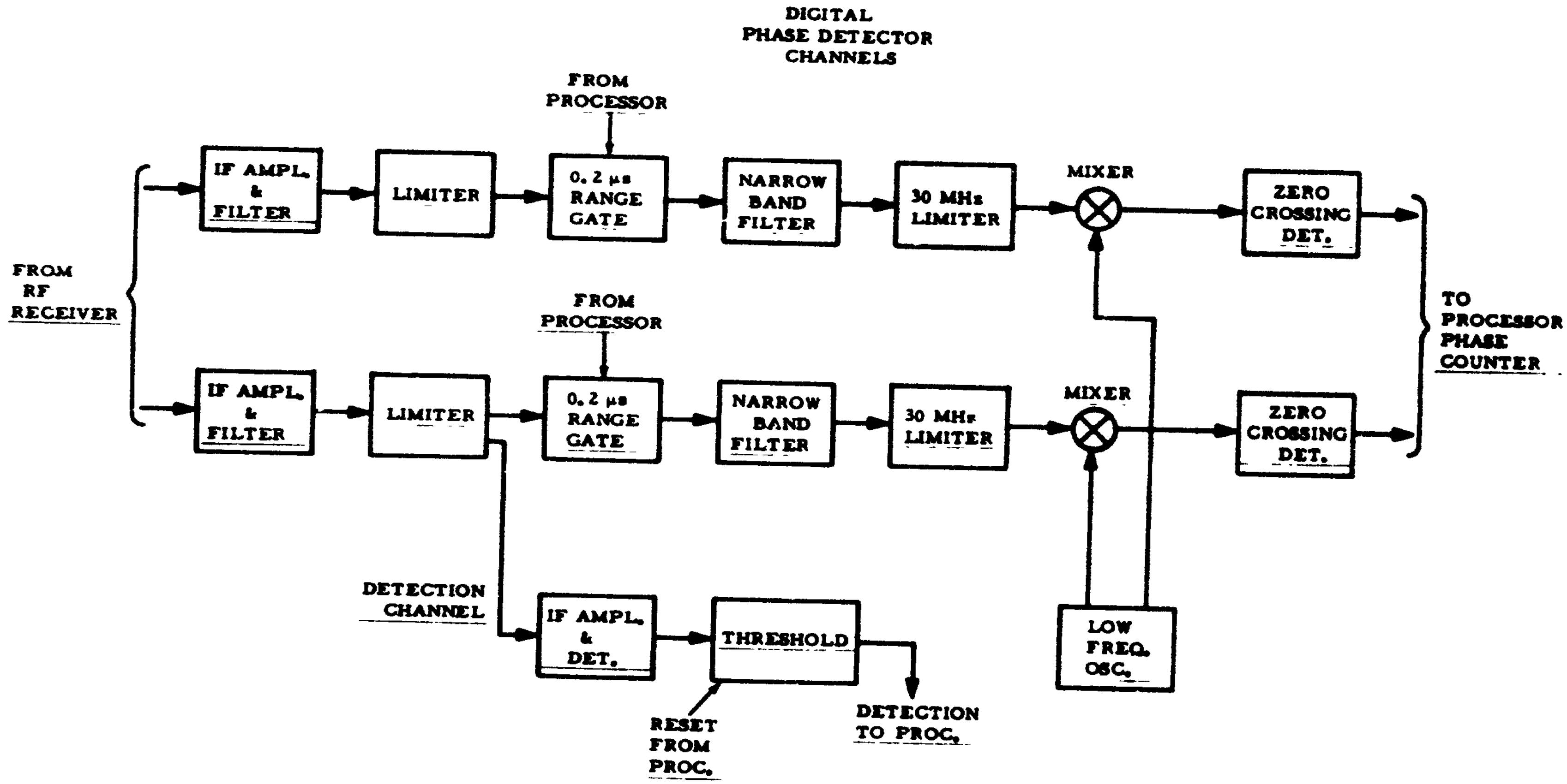


FIGURE 20. GLIDE SLOPE MONITOR IF RECEIVER BLOCK DIAGRAM

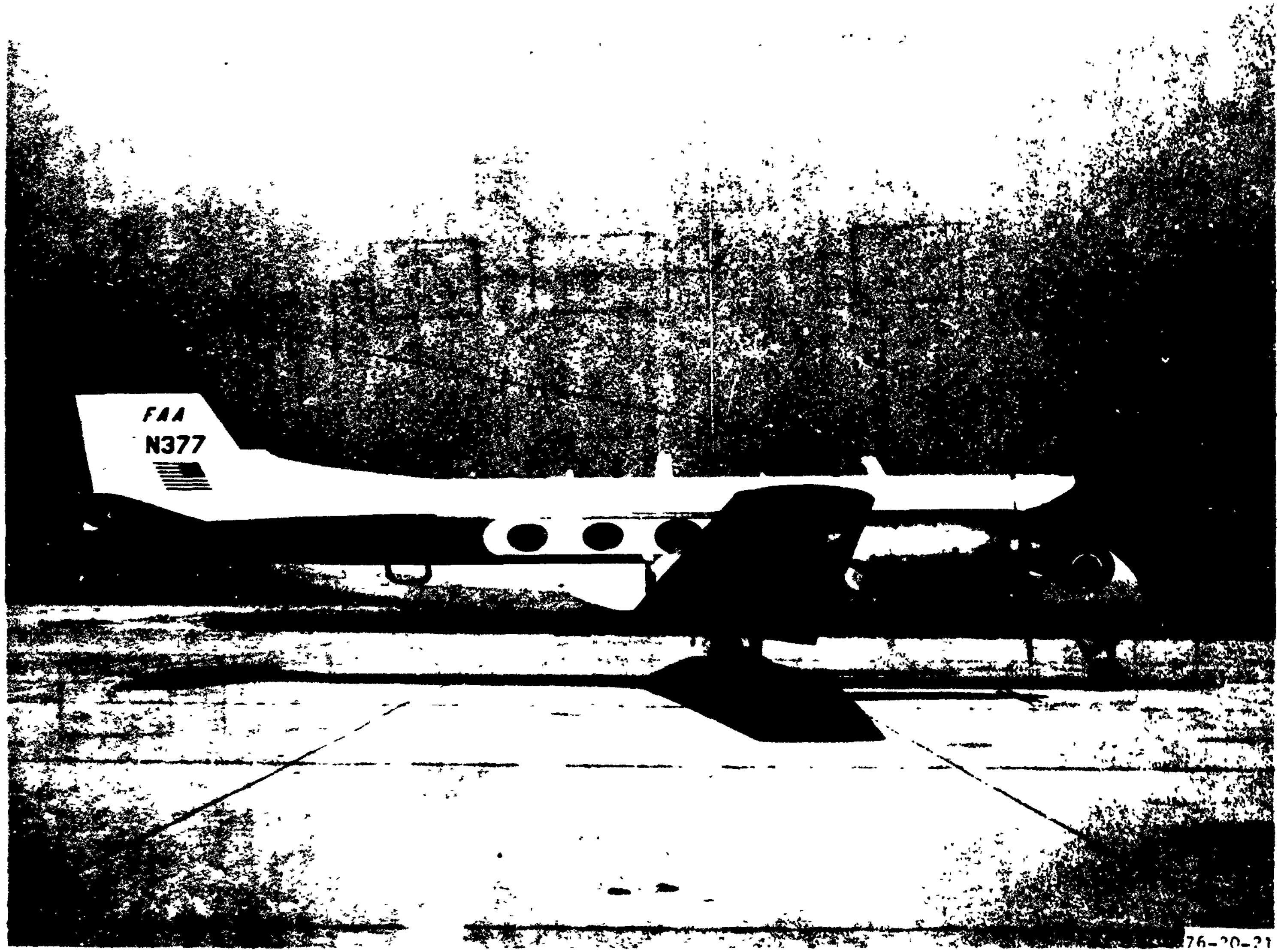


FIGURE 21. GULFSTREAM ONE (N-377) FLIGHT TEST AIRCRAFT

FIGURE 22. COMANCHE (N-9093P) FLIGHT TEST AIRCRAFT

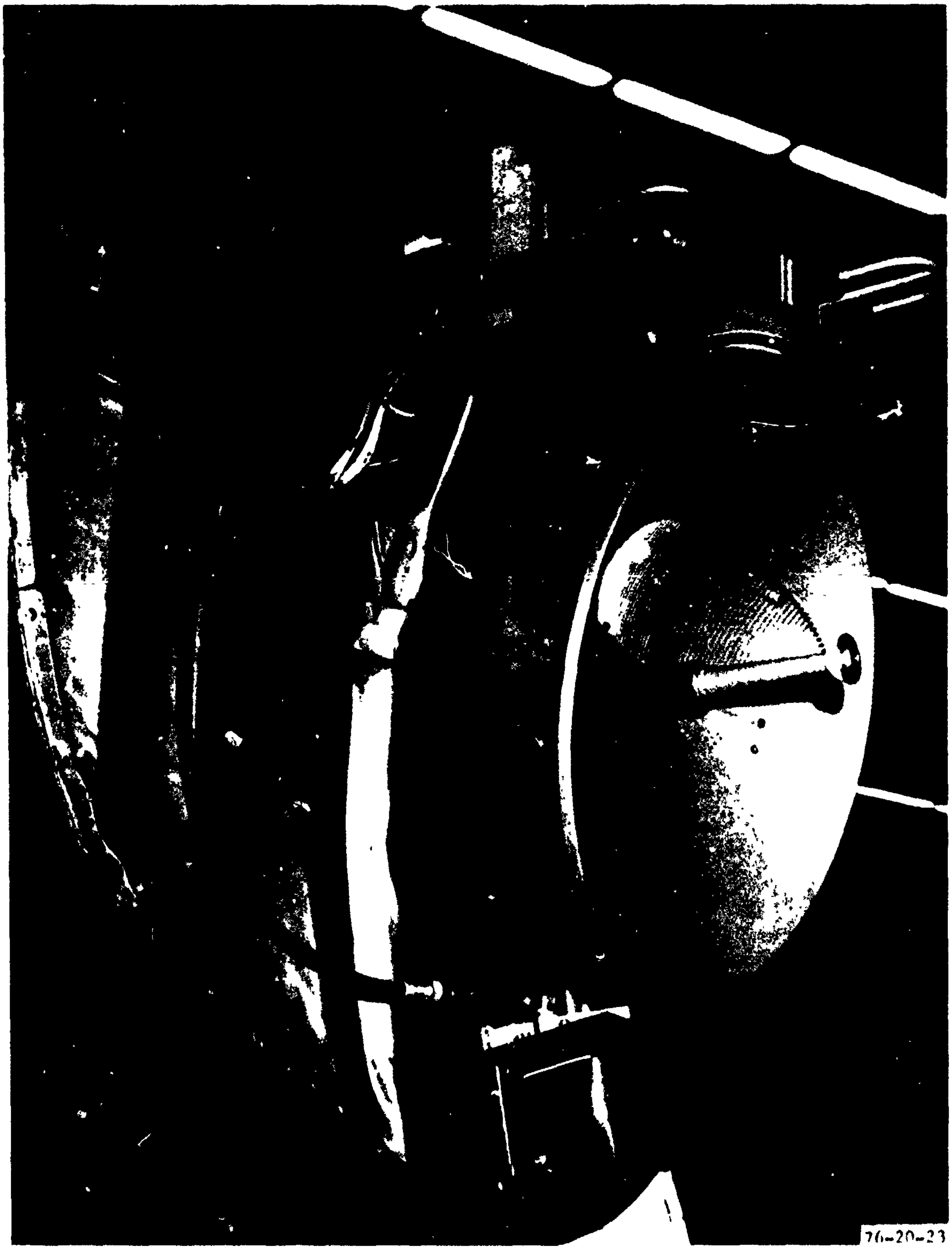
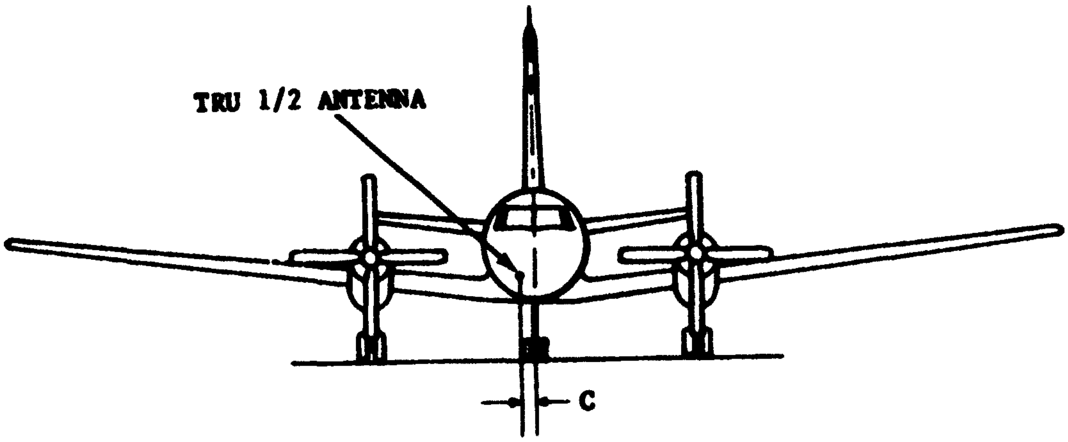
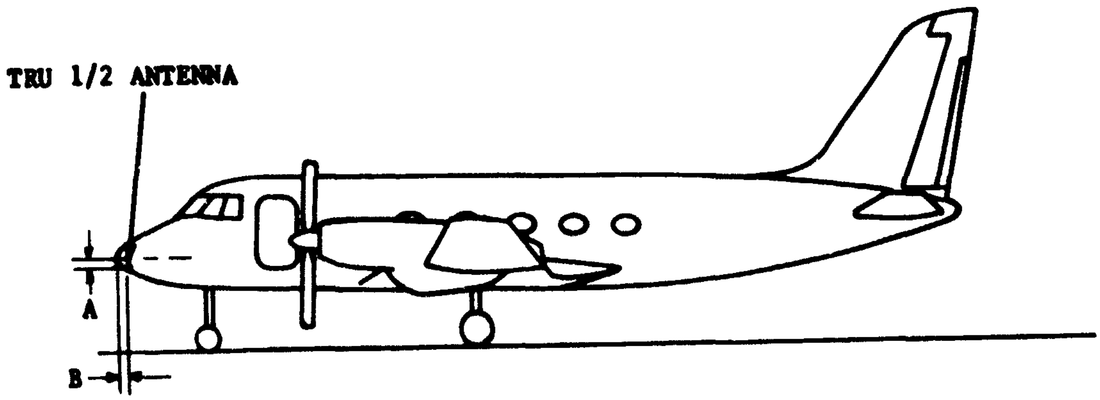


FIGURE 23. GULFSTREAM ONE (N-377) EXPOSED NOSE OF FLIGHT TEST AIRCRAFT



A - 1.0' (0.30481 METERS)
B - 1.0' (0.30481 METERS)
C - 0.083' (0.02530 METERS)



GULFSTREAM ONE (N-377)

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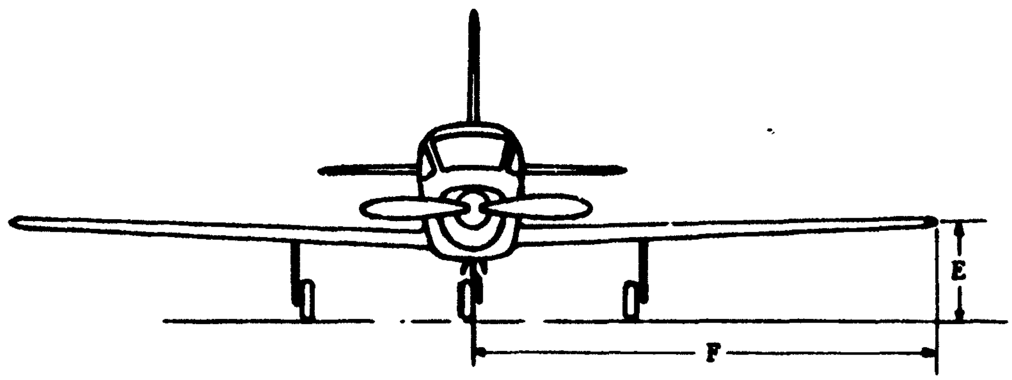
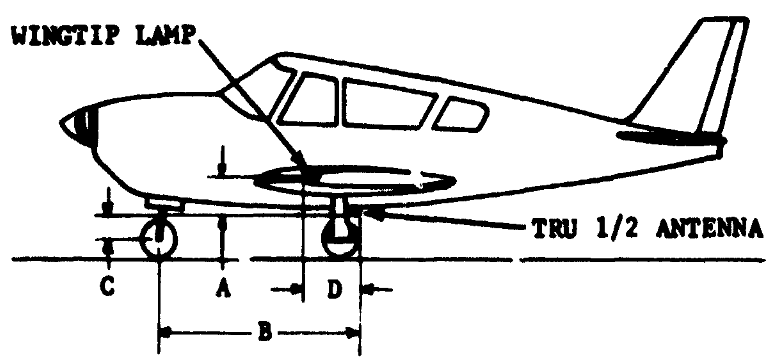
FIGURE 24-1. PHOTOTHEODOLITE AIRCRAFT TRACKING POINTS AND RELATED AIRCRAFT TRU-1/2 ANTENNA LOCATION INFORMATION-SHEET 1 OF 2



A - 1.5' (0.45722 METERS)
B - 7.34' (2.23731 METERS)
C - 1.0' (0.30481 METERS)
D - 3.84' (1.17047 METERS)
E - 2.5' (0.76203 METERS)
F - 17.5' (5.33418 METERS)

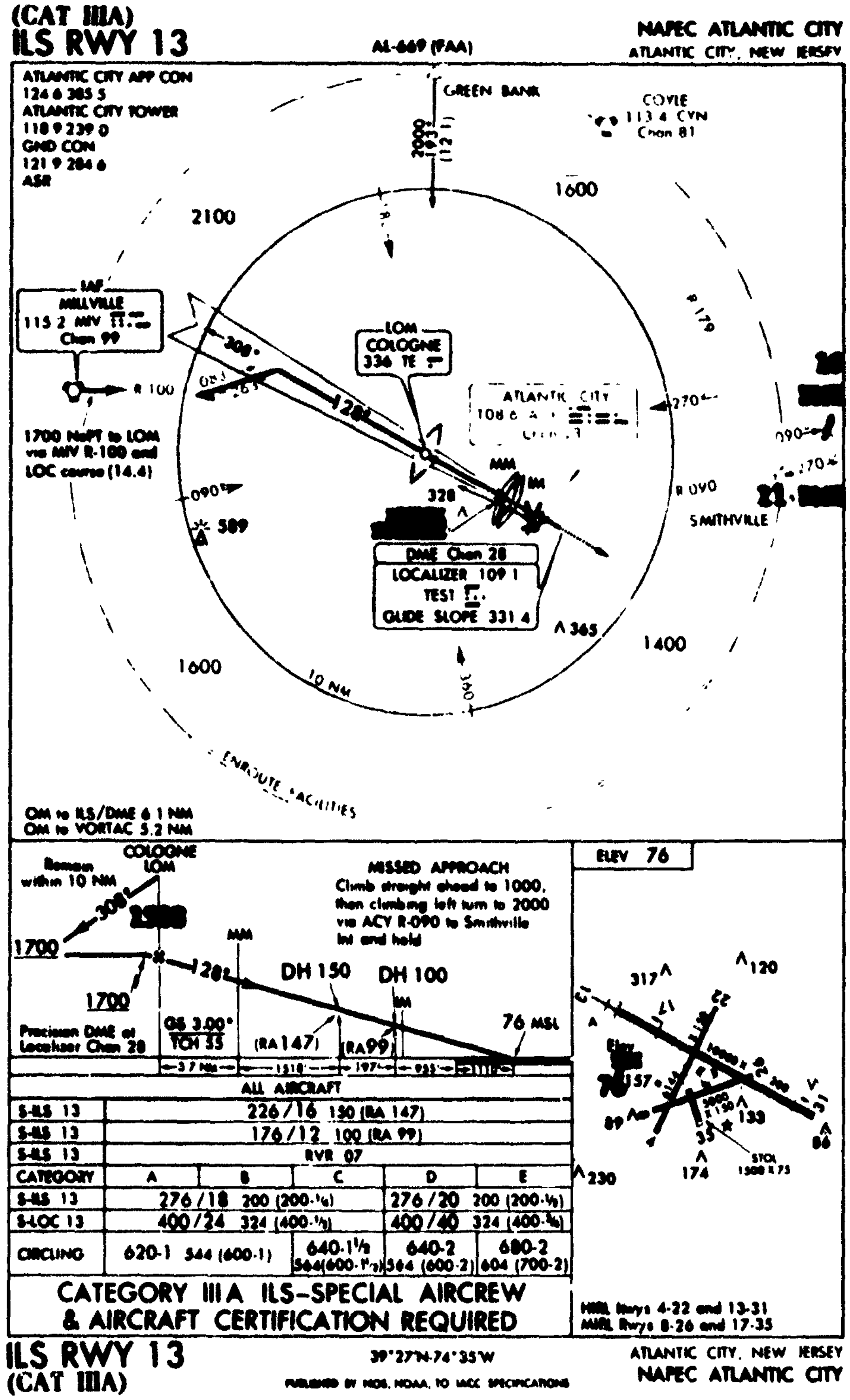


COMANCHE (N-9093P)

76-20-24-2

FIGURE 24-2. PHOTOTHEODOLITE AIRCRAFT TRACKING POINTS AND RELATED AIRCRAFT TRU-1/2 ANTENNA LOCATION INFORMATION-SHEET 2 OF 2

EXPERIMENTAL USE ONLY



76-20-25

FIGURE 25. ILS RUNWAY 13 FLIGHT CHART (EXPERIMENTAL USE ONLY)

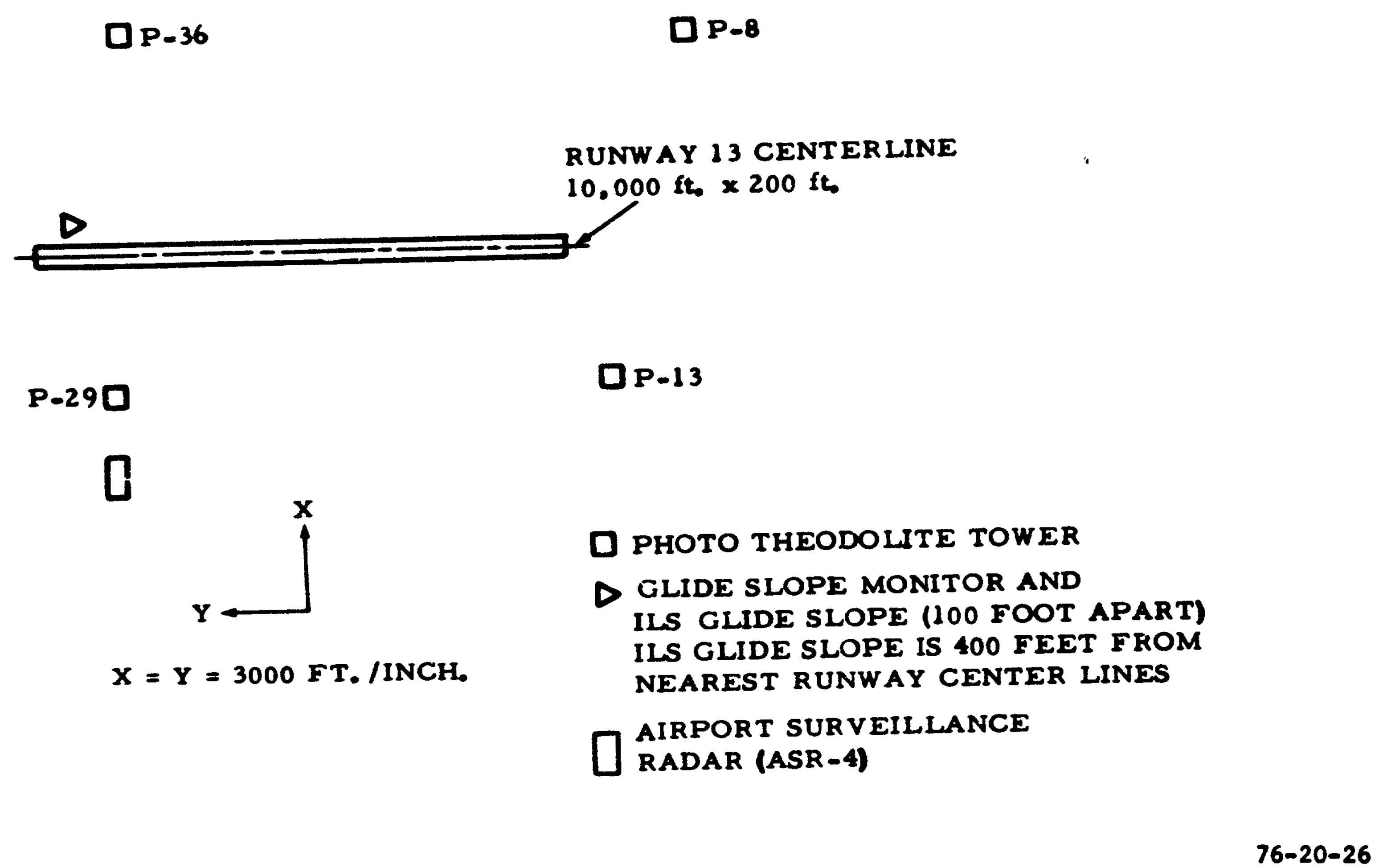
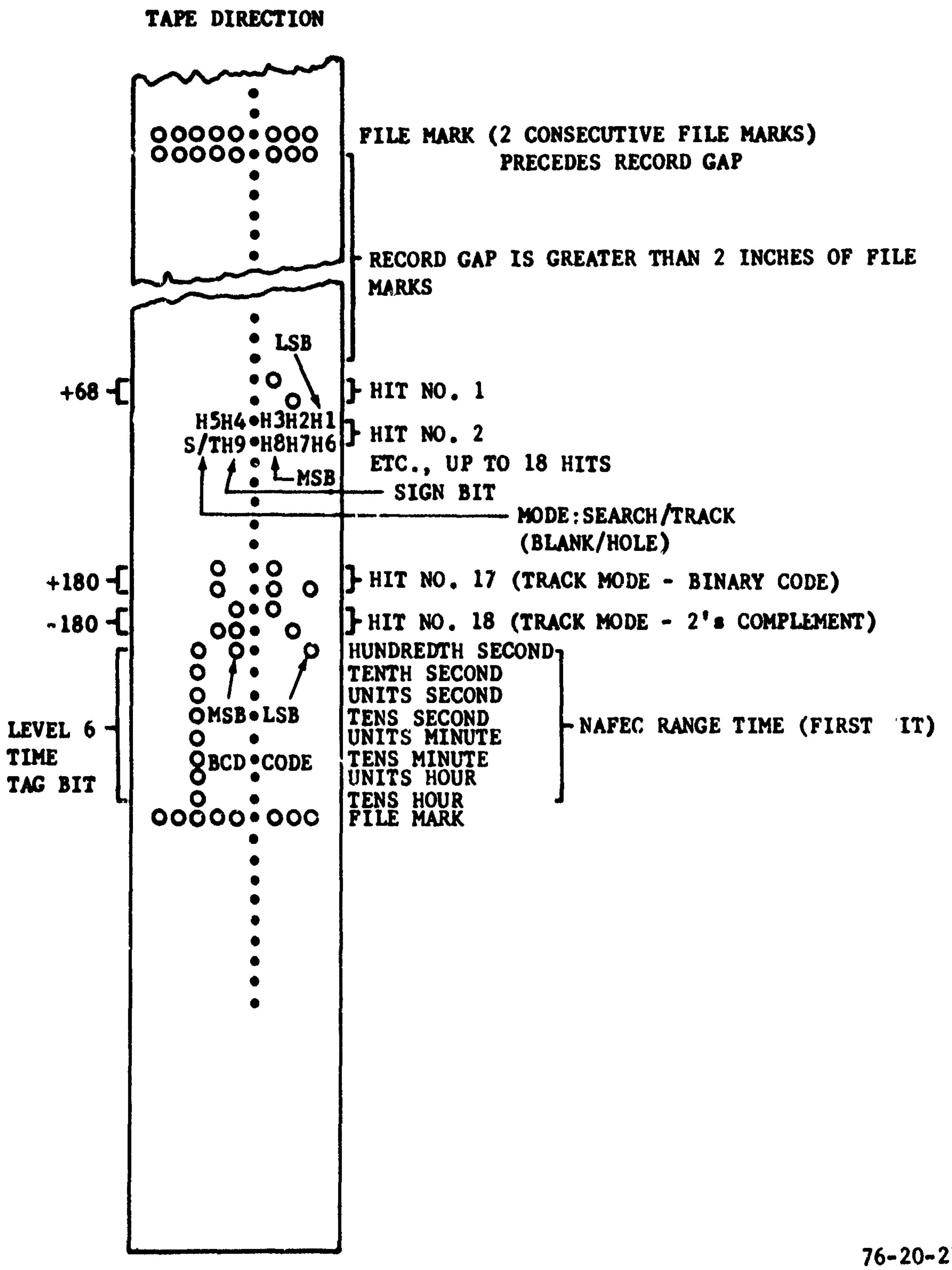
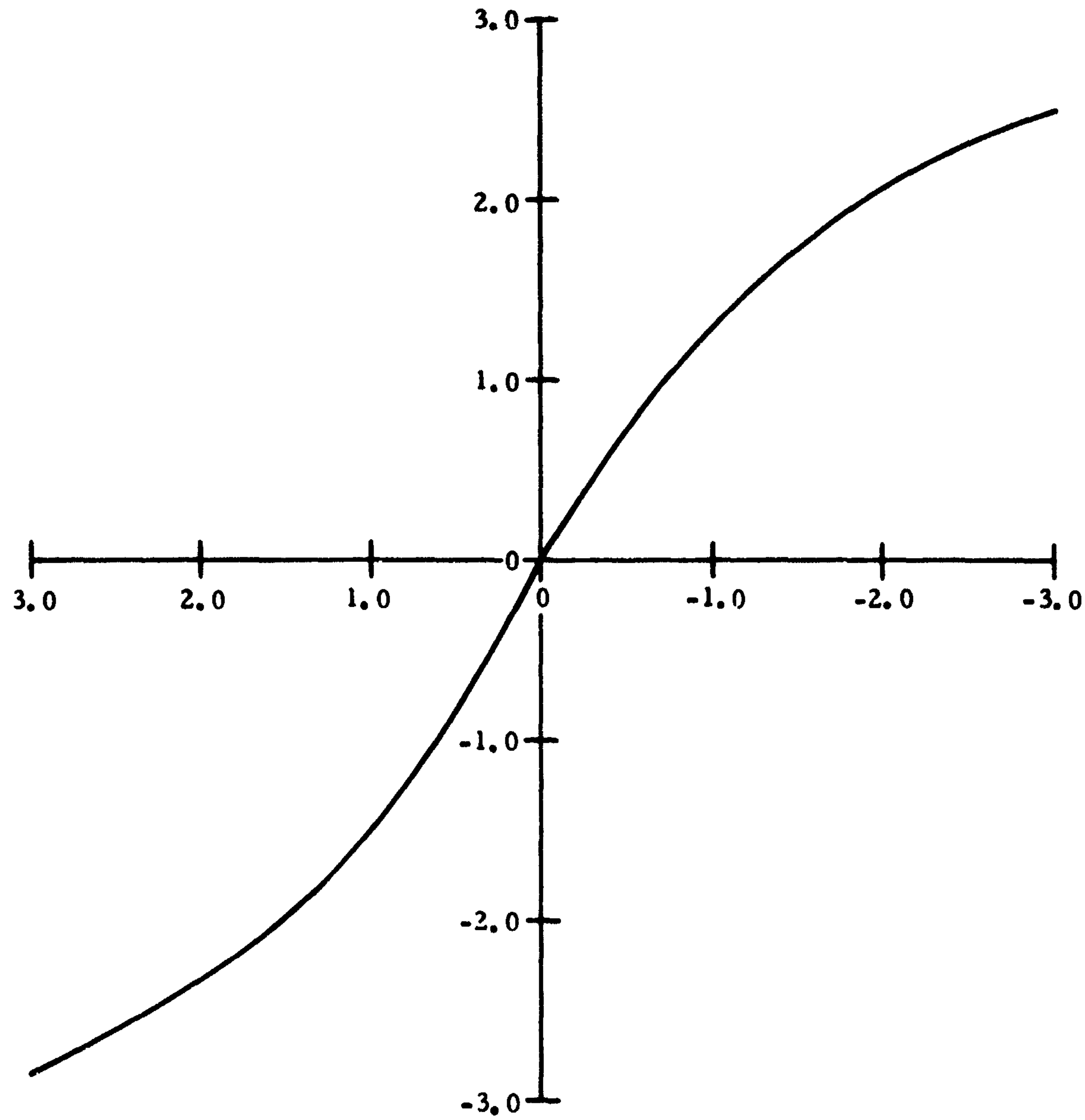


FIGURE 26. NAFEC DATA COLLECTION SYSTEM SCALE LAYOUT



76-20-27

FIGURE 27. GLIDE SLOPE MONITOR SUBSYSTEM PUNCHED PAPER TAPE FORMAT



76-20-28

FIGURE 28. GLIDE SLOPE MONITOR SUBSYSTEM ANTENNA DISCRIMINATOR CURVE

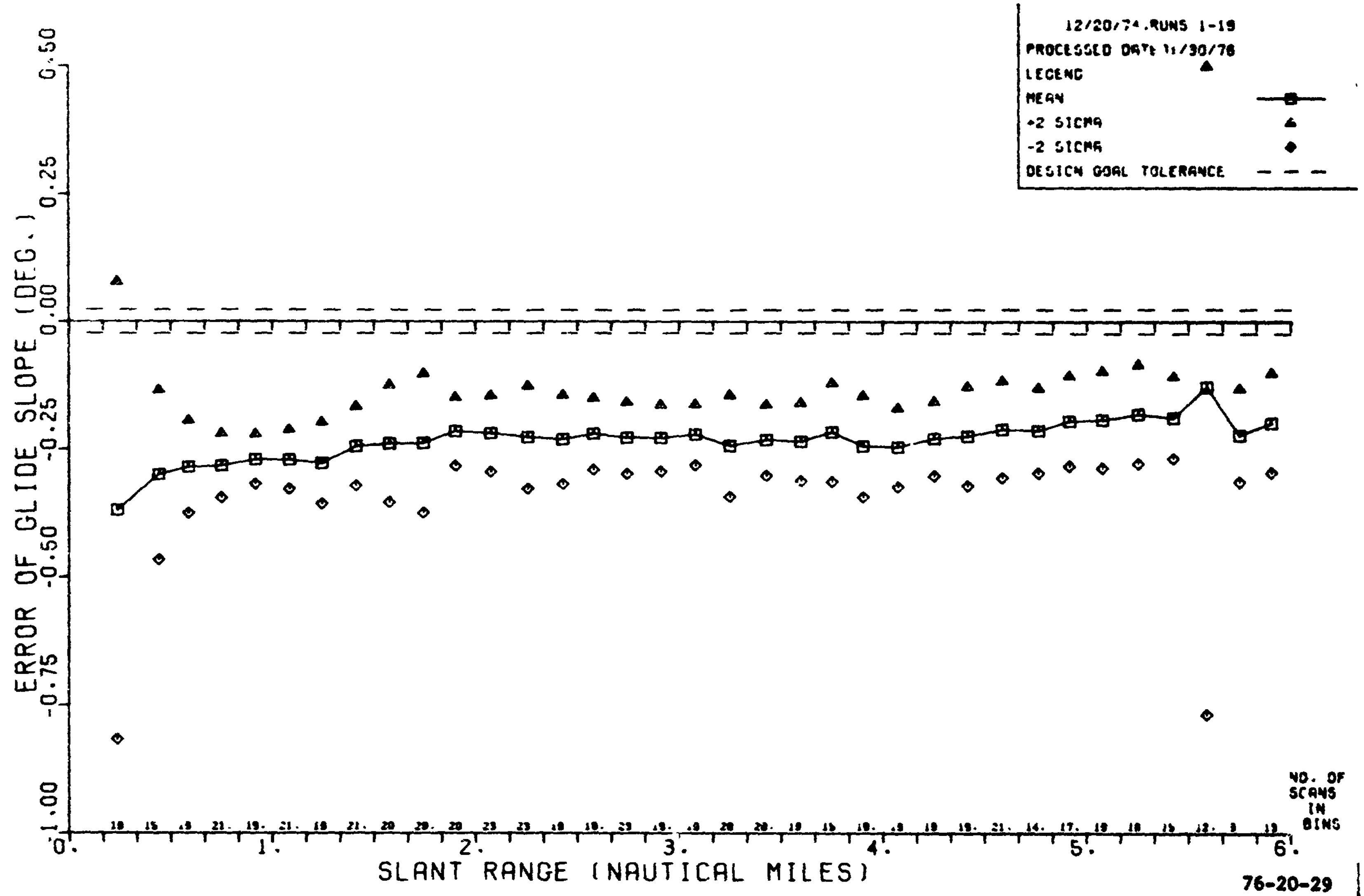


FIGURE 29. DECEMBER 20, 1974, FLIGHT PERIOD OF N-377 ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

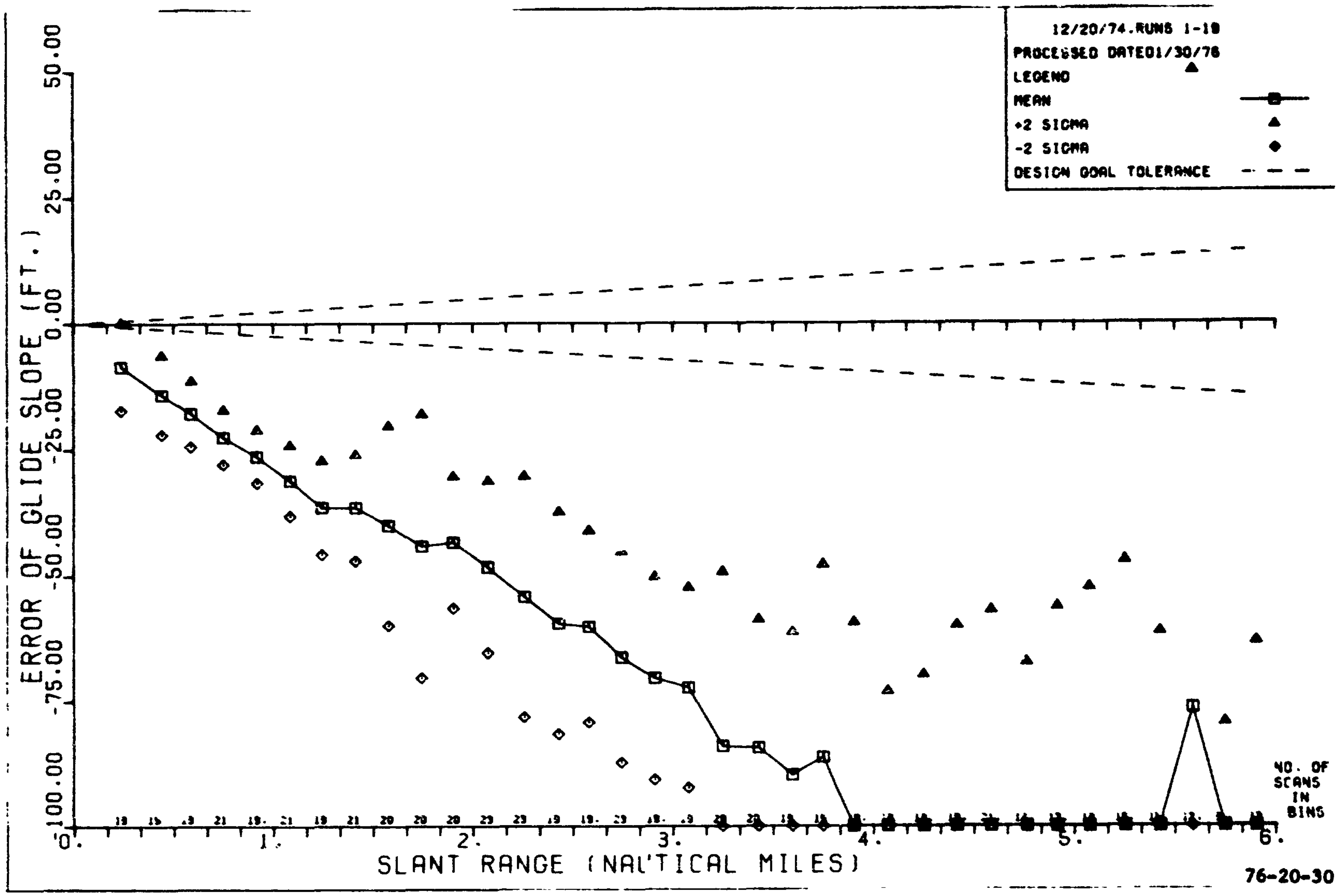


FIGURE 30. DECEMBER 20, 1974, FLIGHT PERIOD CF N-377 ON THE 3° ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET

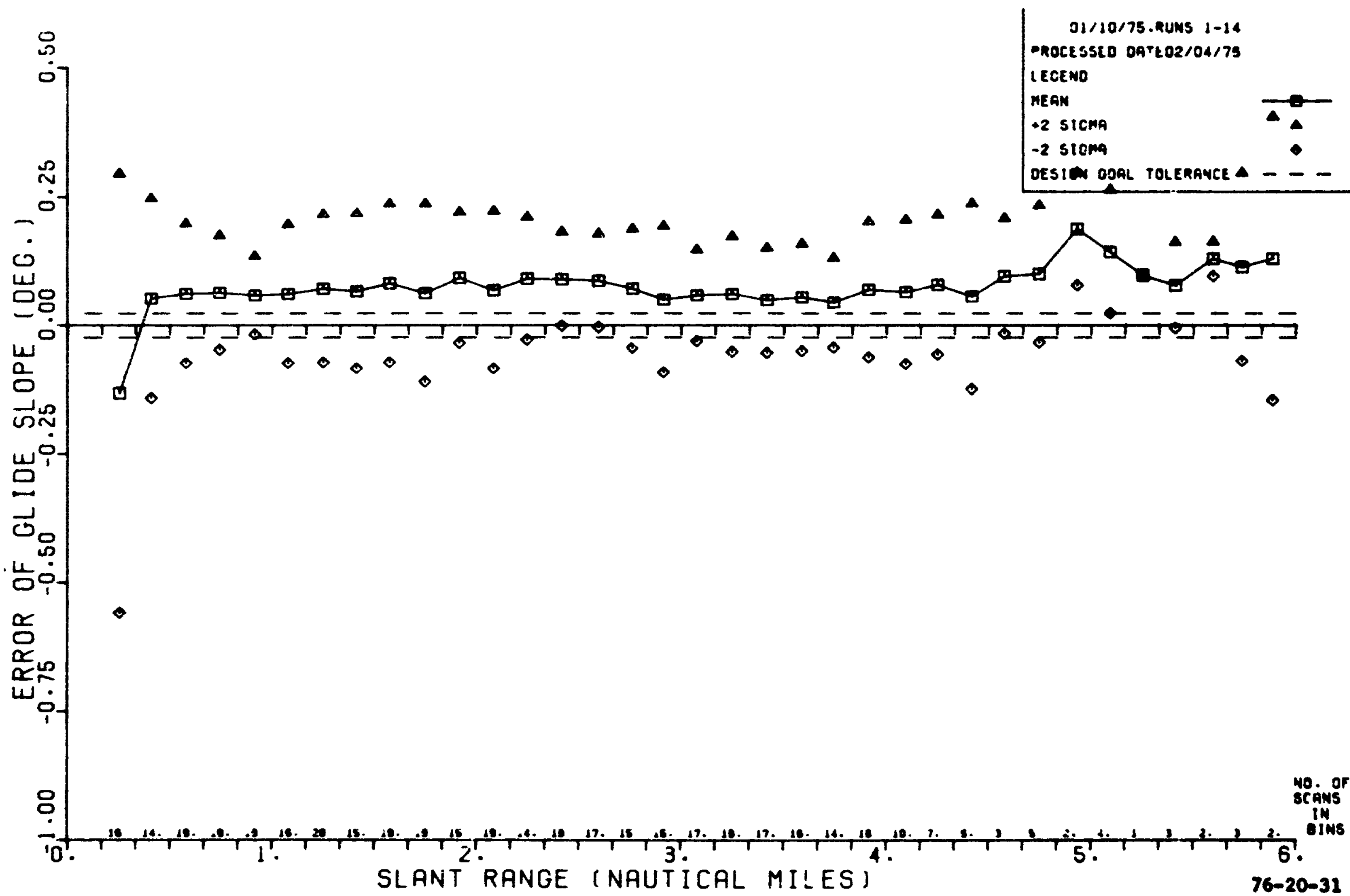


FIGURE 31. JANUARY 10, 1975, FLIGHT PERIOD OF N-377 ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

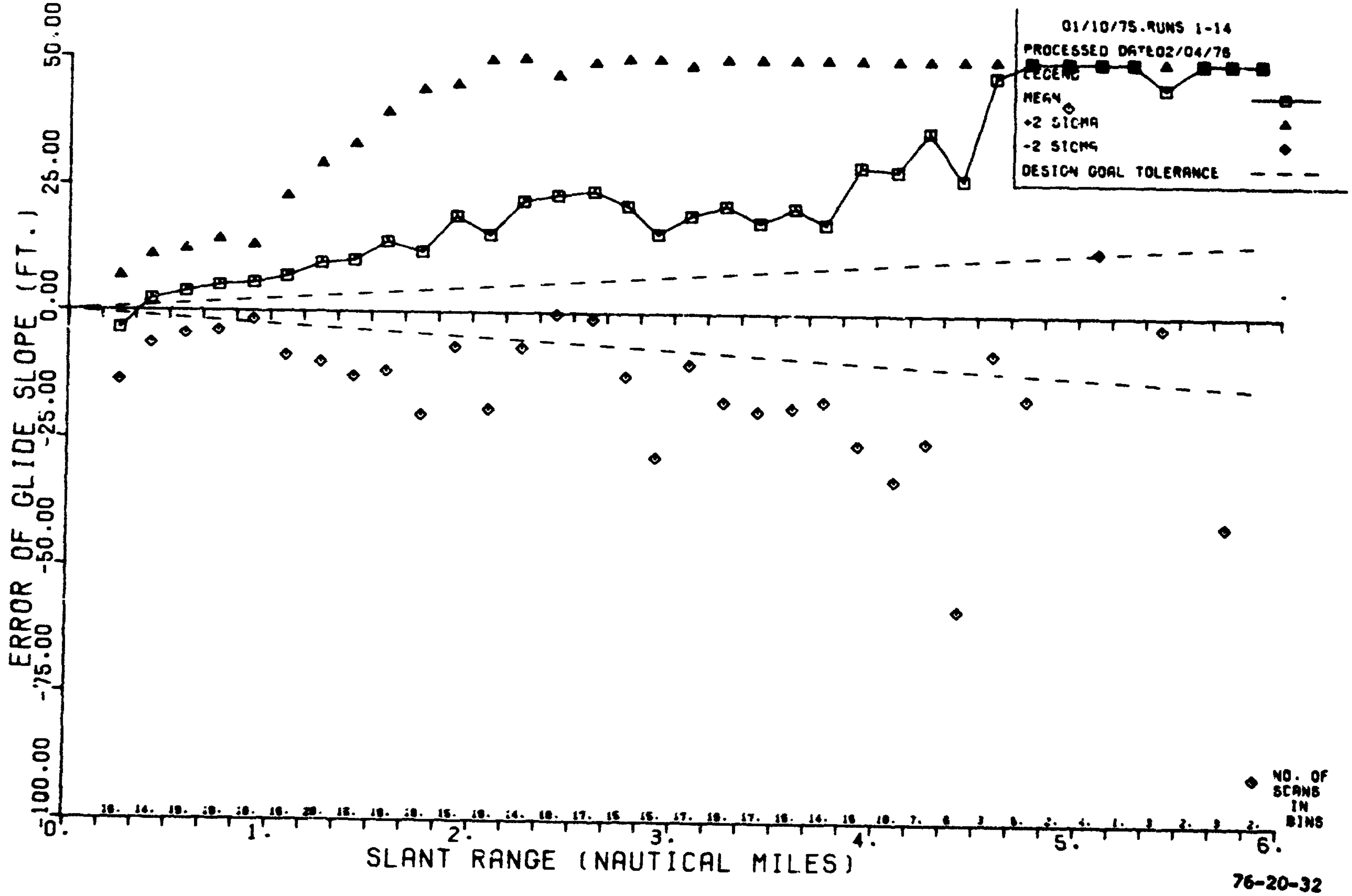


FIGURE 32. JANUARY 10, 1975, FLIGHT PERIOD OF N-377 ON THE 3° ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET

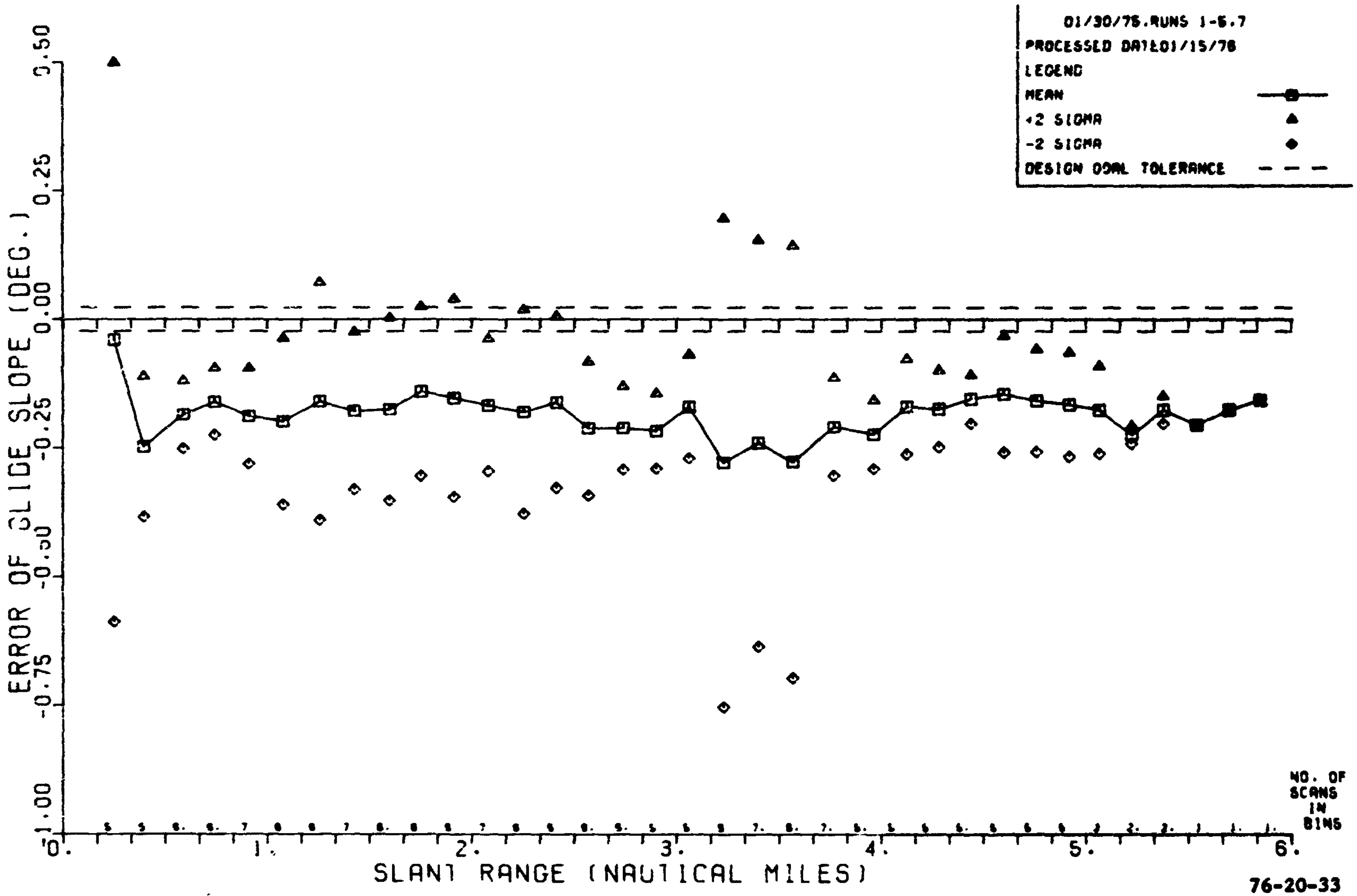


FIGURE 33. JANUARY 30, 1975, FLIGHT PERIOD OF N-377 ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

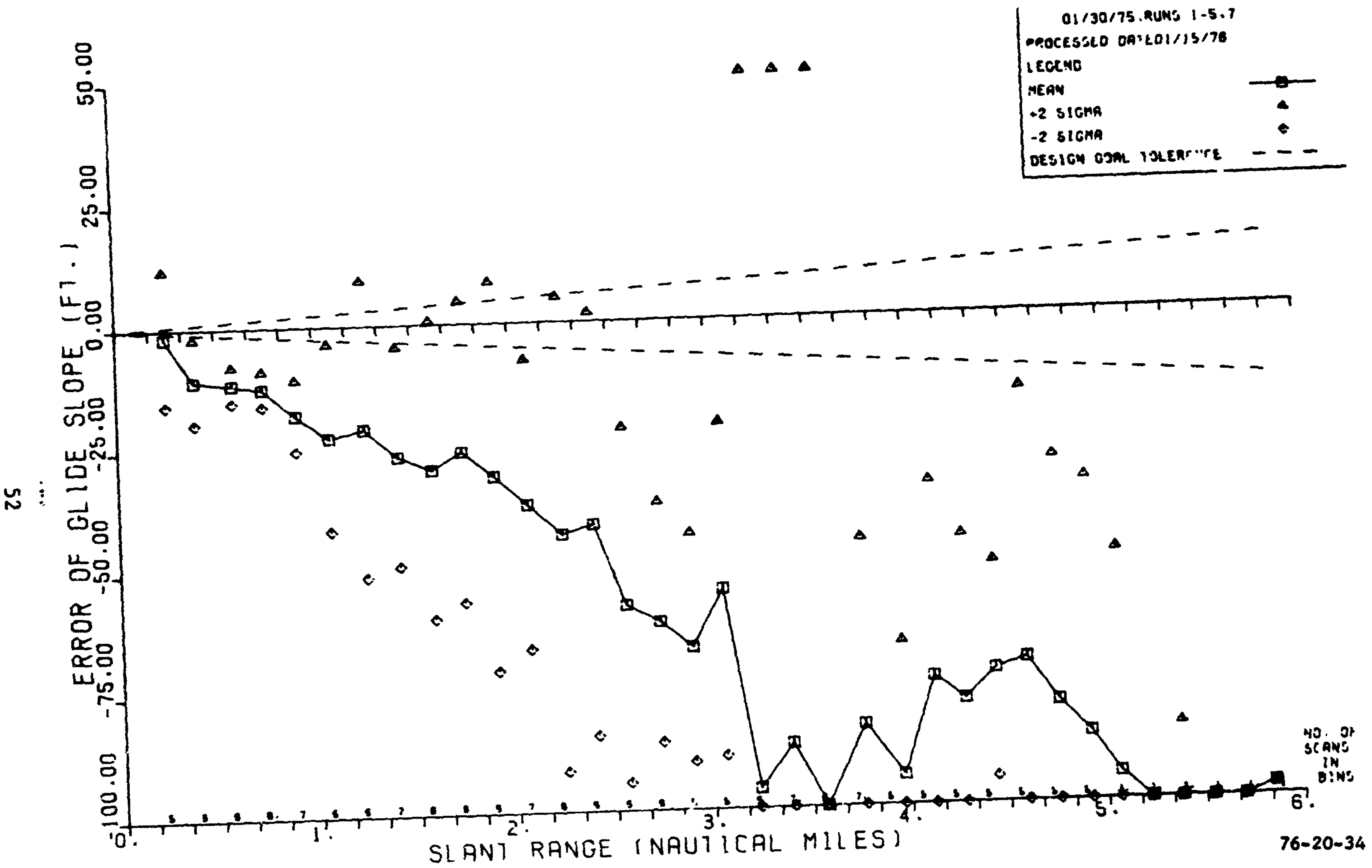


FIGURE 34. JANUARY 30, 1975, FLIGHT PERIOD OF N-377 ON THE 3° ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET

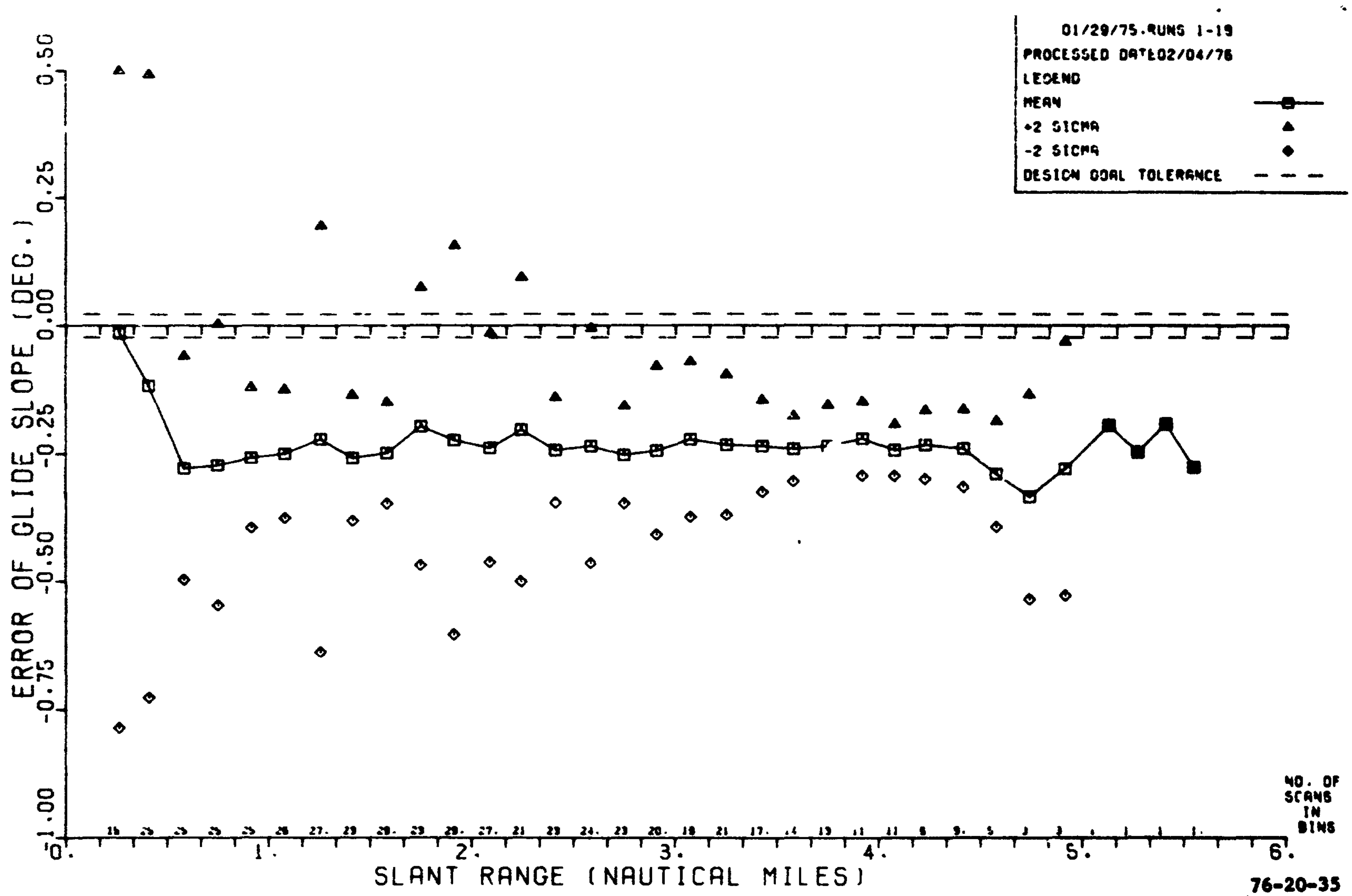


FIGURE 35. JANUARY 29, 1975, FLIGHT PERIOD OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

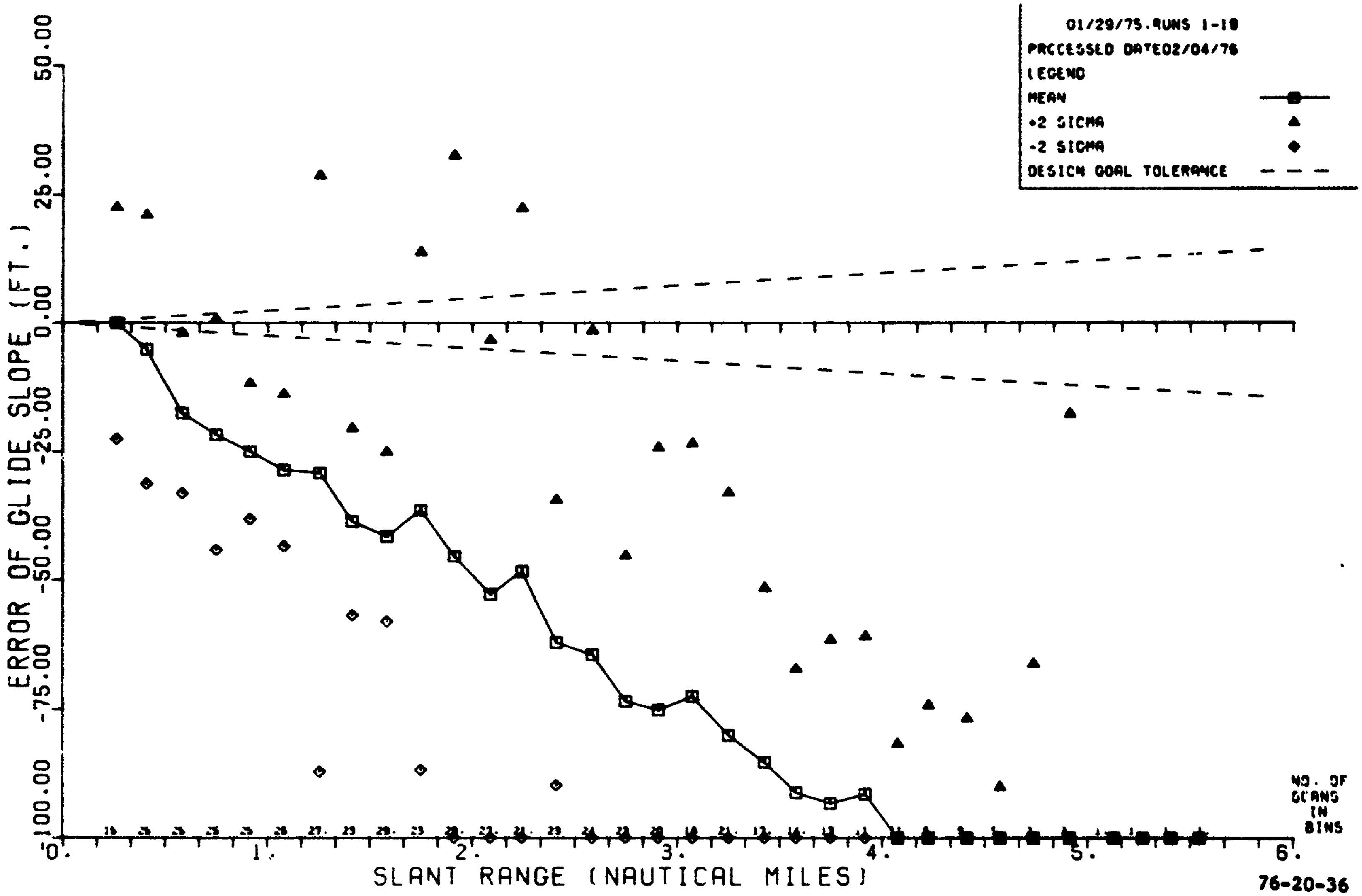


FIGURE 36. JANUARY 29, 1975, FLIGHT PERIOD OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET

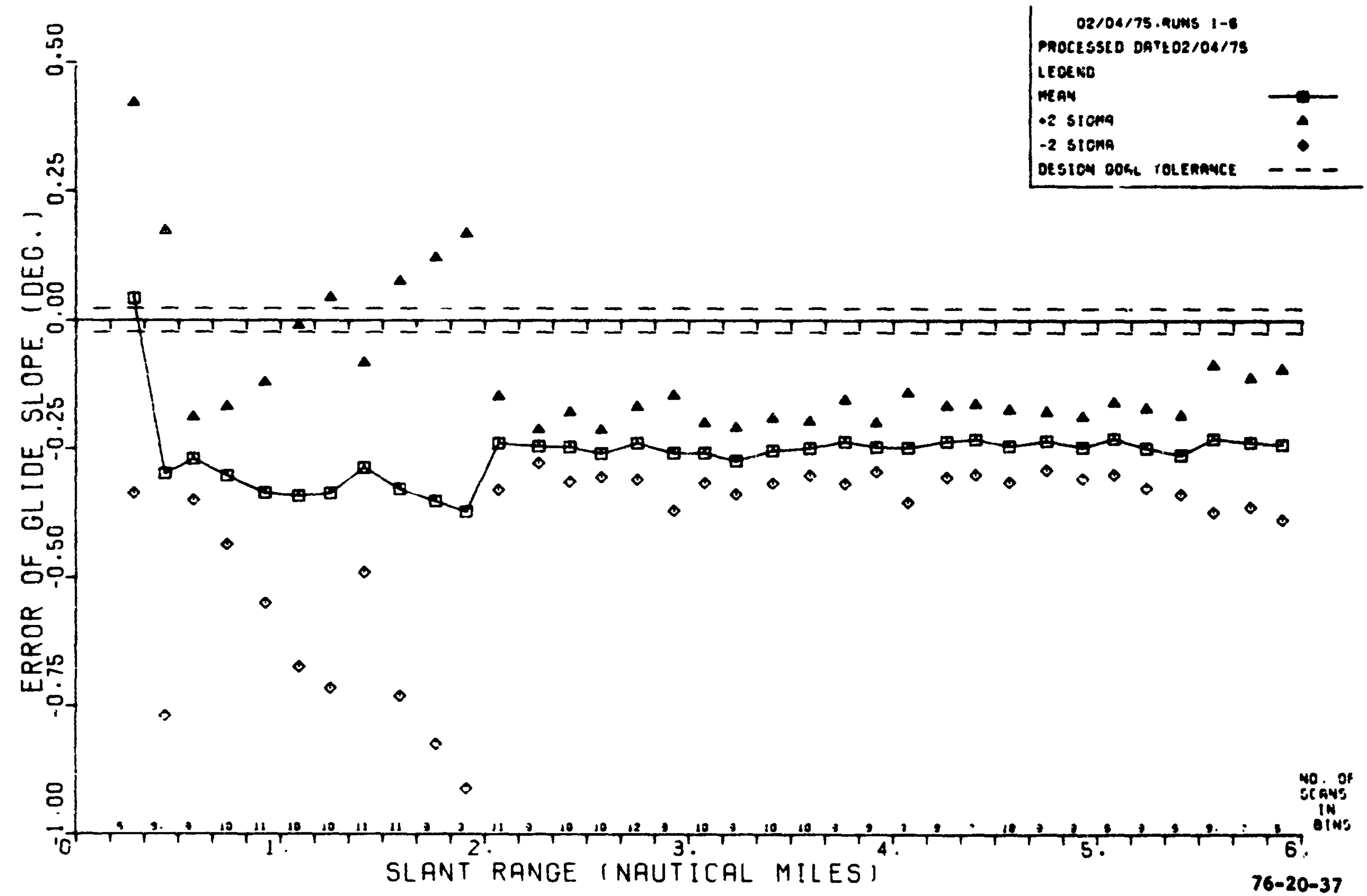


FIGURE 37. FEBRUARY 4, 1975, FLIGHT PERIOD OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

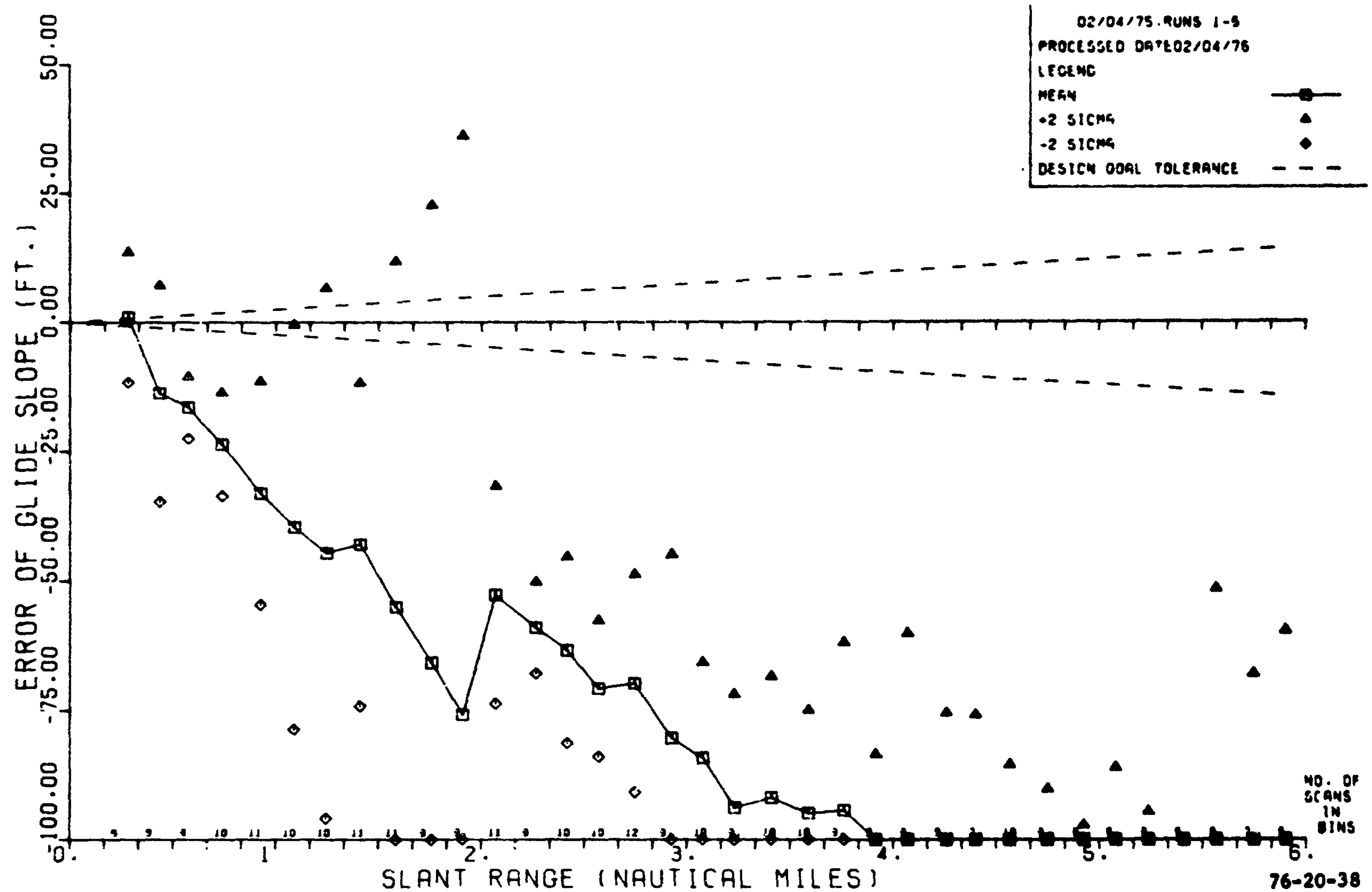
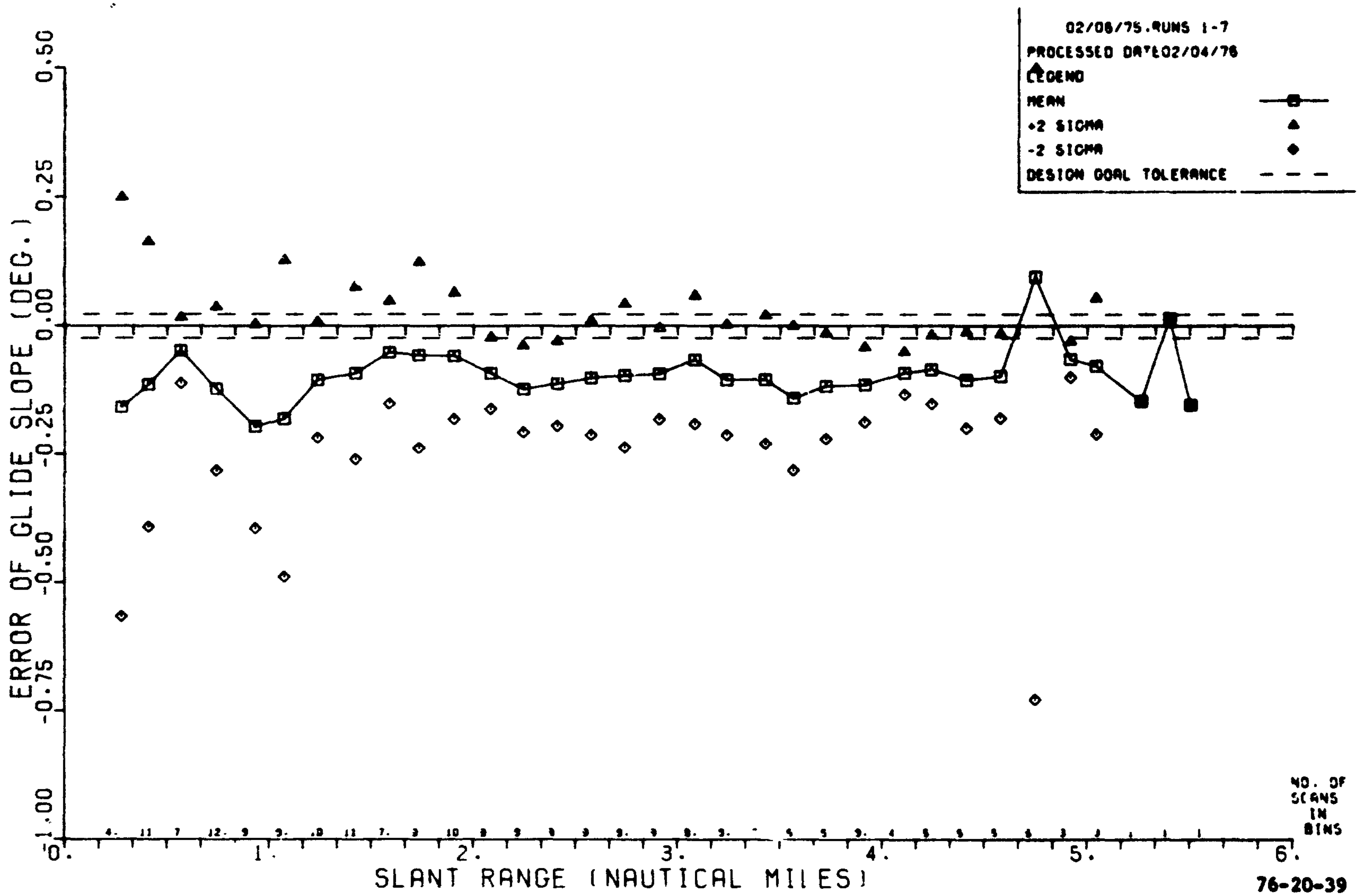


FIGURE 38. FEBRUARY 4, 1975, FLIGHT PERIOD OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET



76-20-39

FIGURE 39. FEBRUARY 6, 1975, FLIGHT PERIOD OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

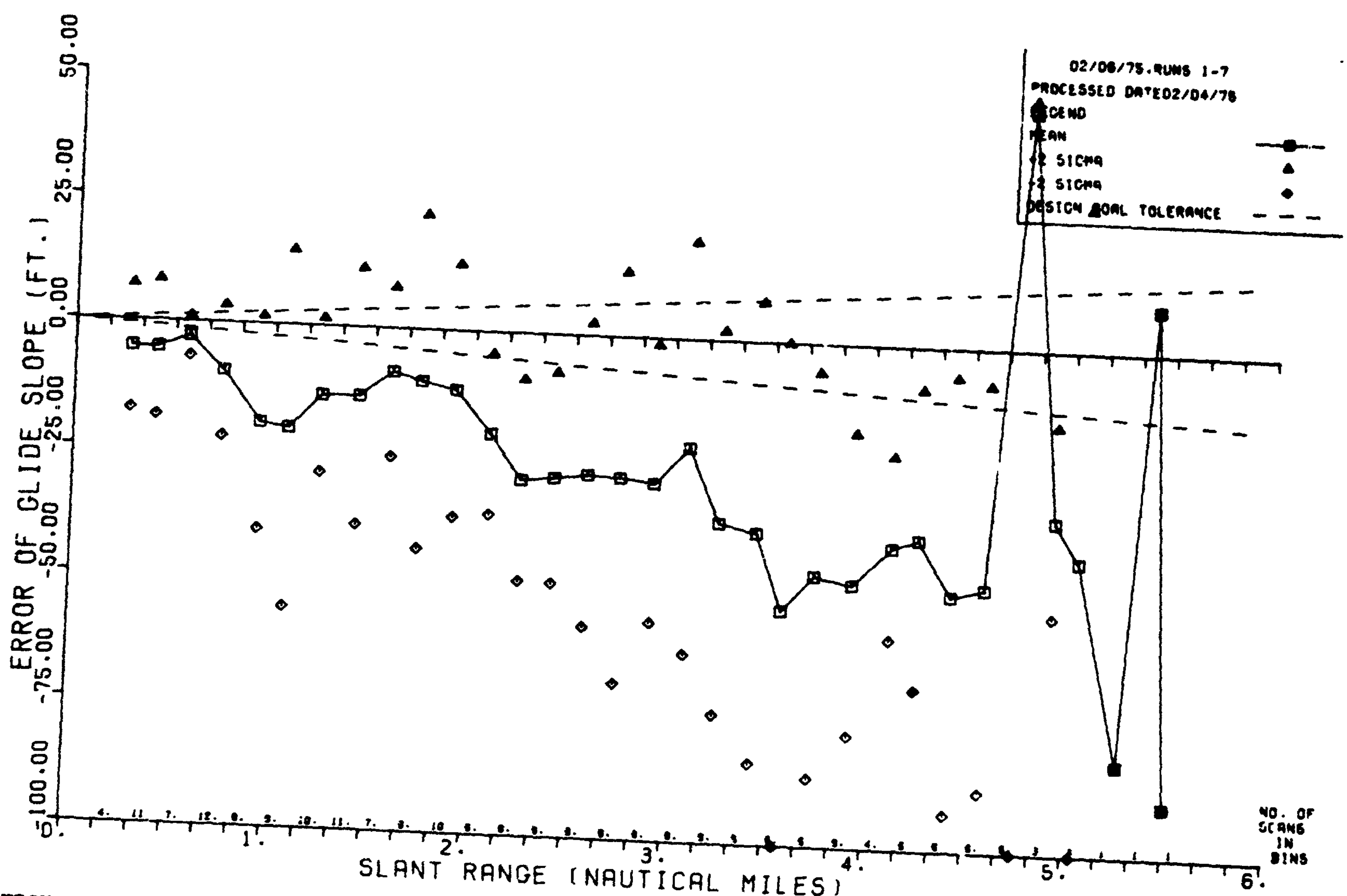


FIGURE 40. FEBRUARY 6, 1975, FLIGHT PERIOD OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET

76-20-40

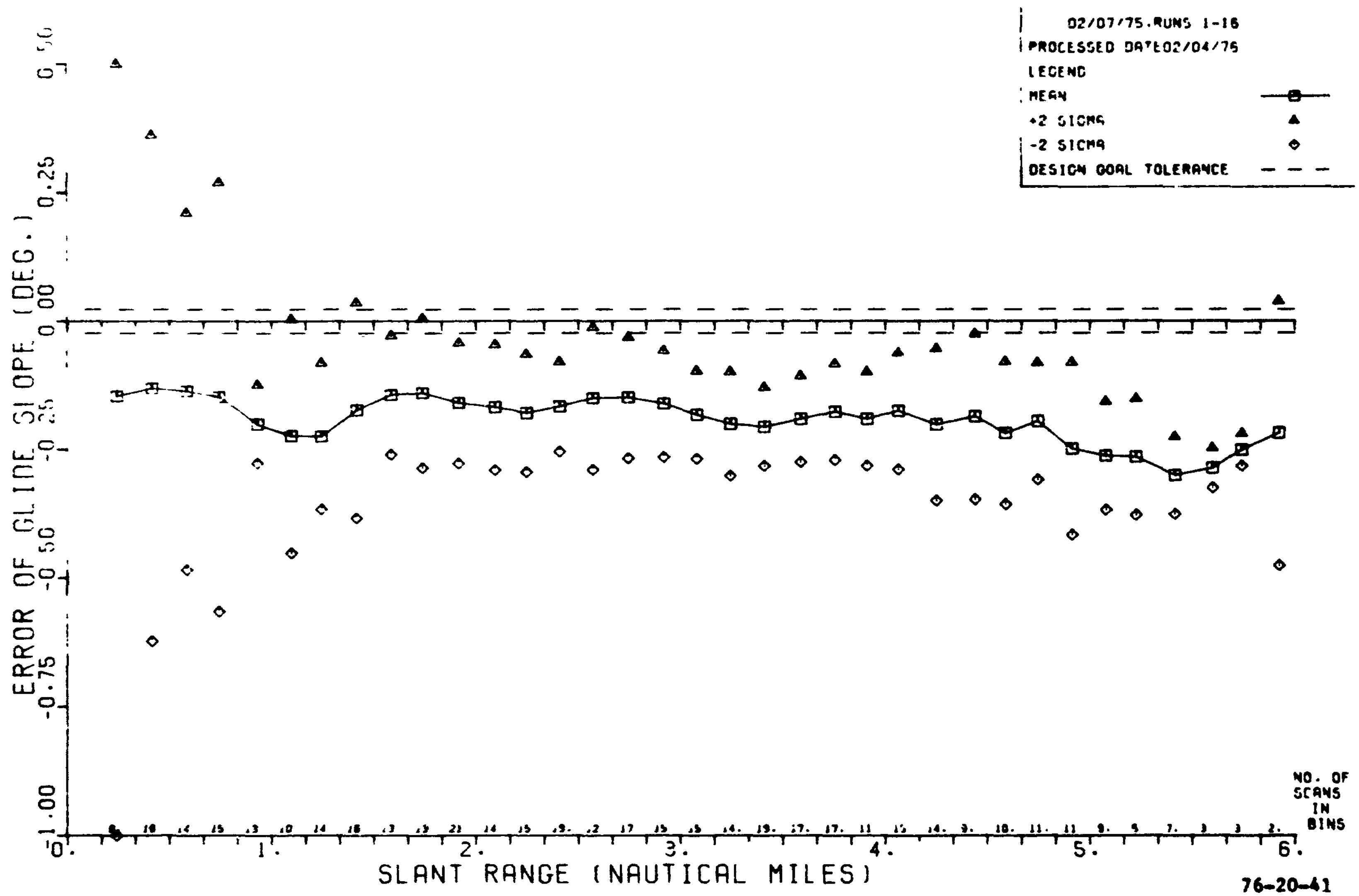


FIGURE 41. FEBRUARY 7, 1975, FLIGHT PERIOD OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

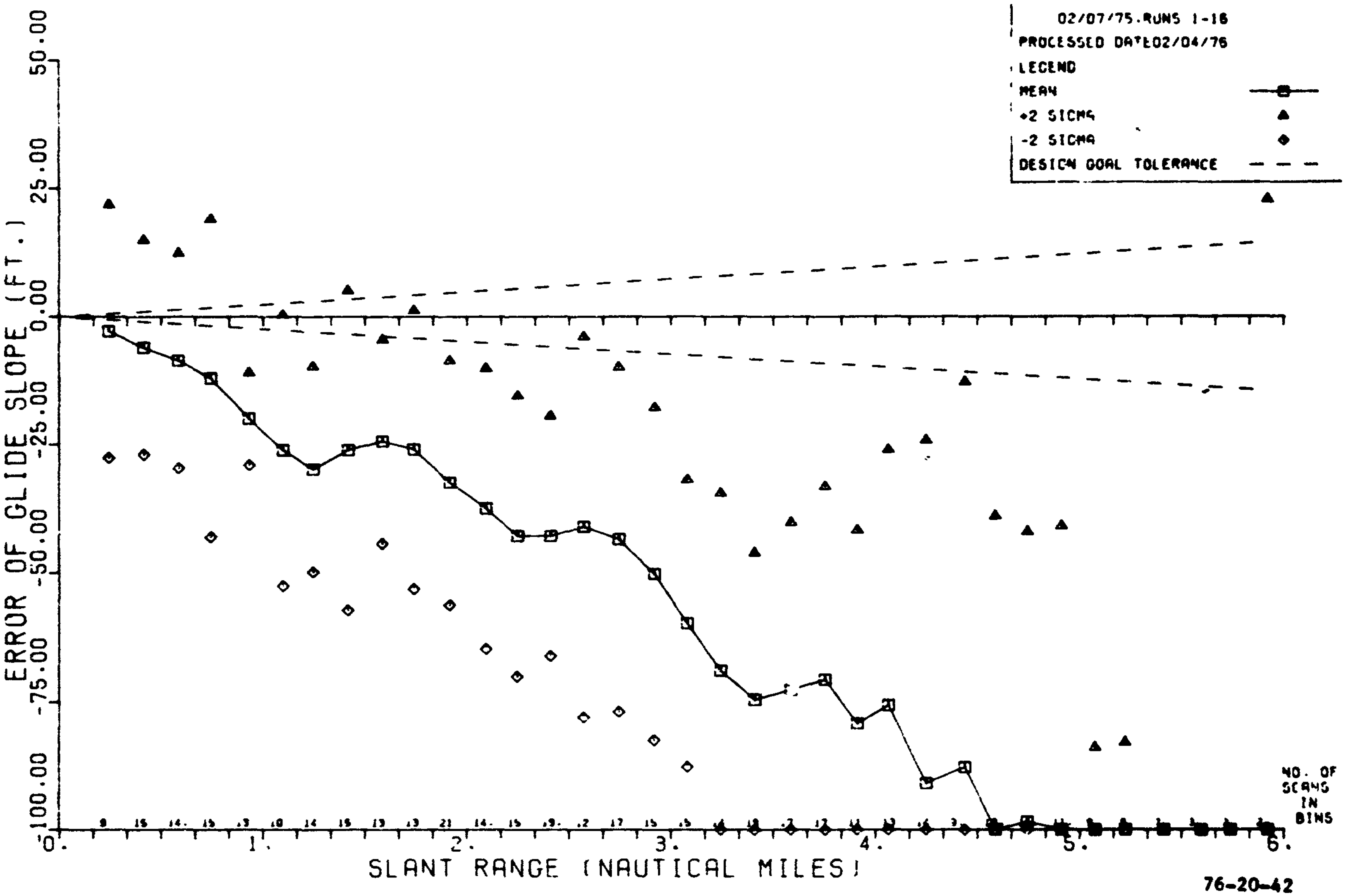


FIGURE 42. FEBRUARY 7, 1975, FLIGHT PERIOD OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

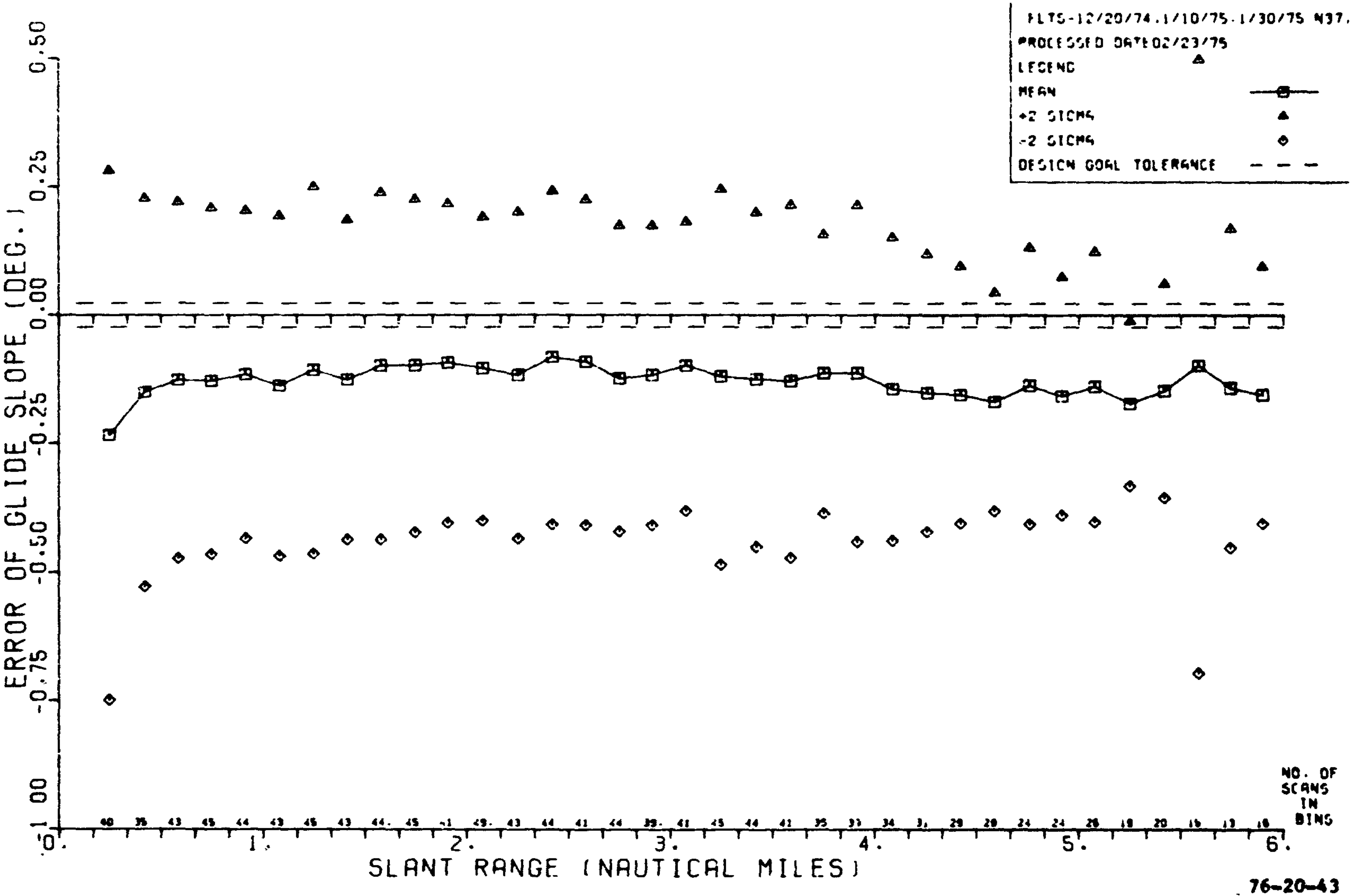


FIGURE 43. ALL FLIGHT PERIODS OF N-377 ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

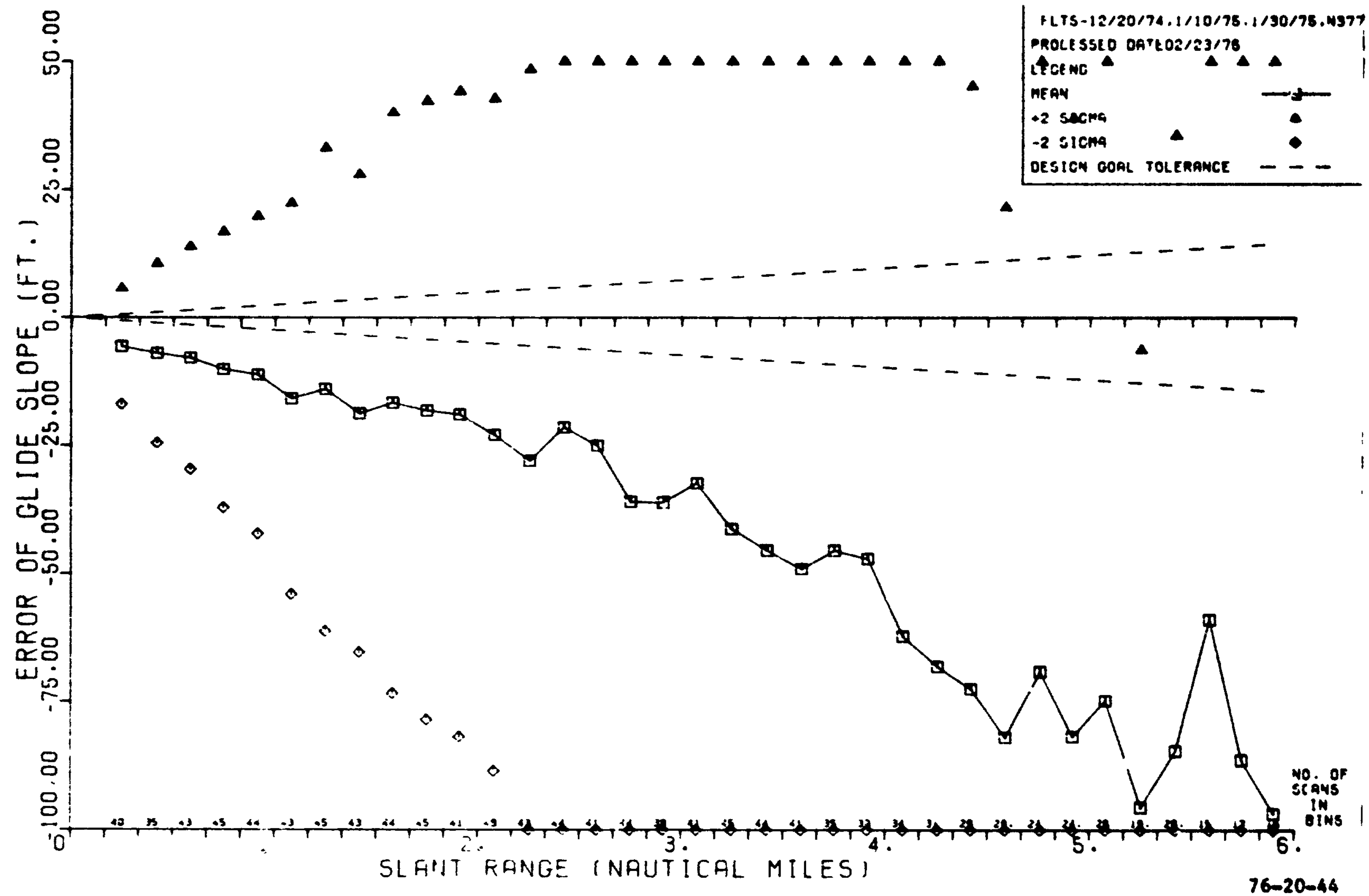


FIGURE 44. ALL FLIGHT PERIODS OF N-377 ON THE 3° ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET

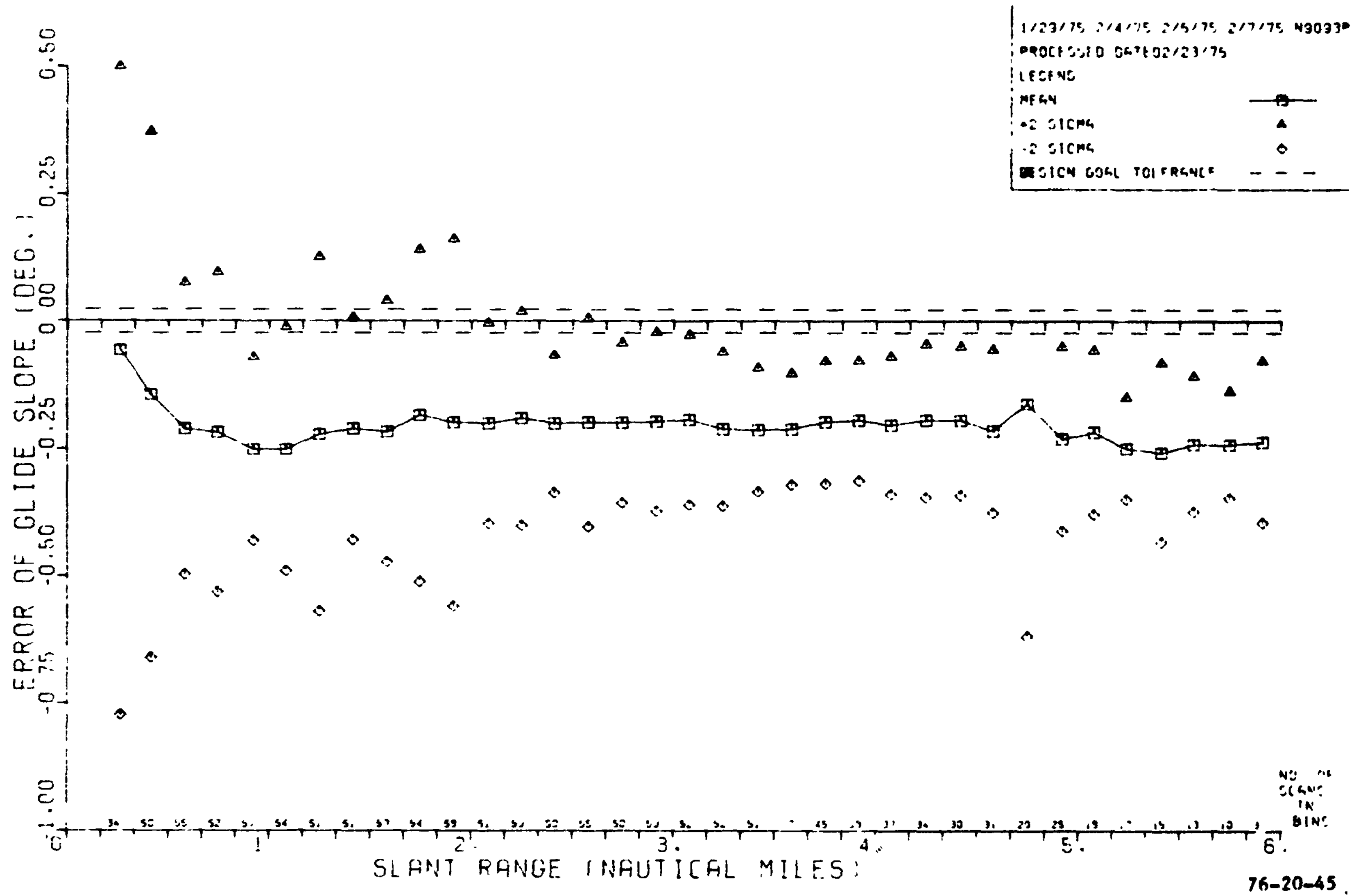
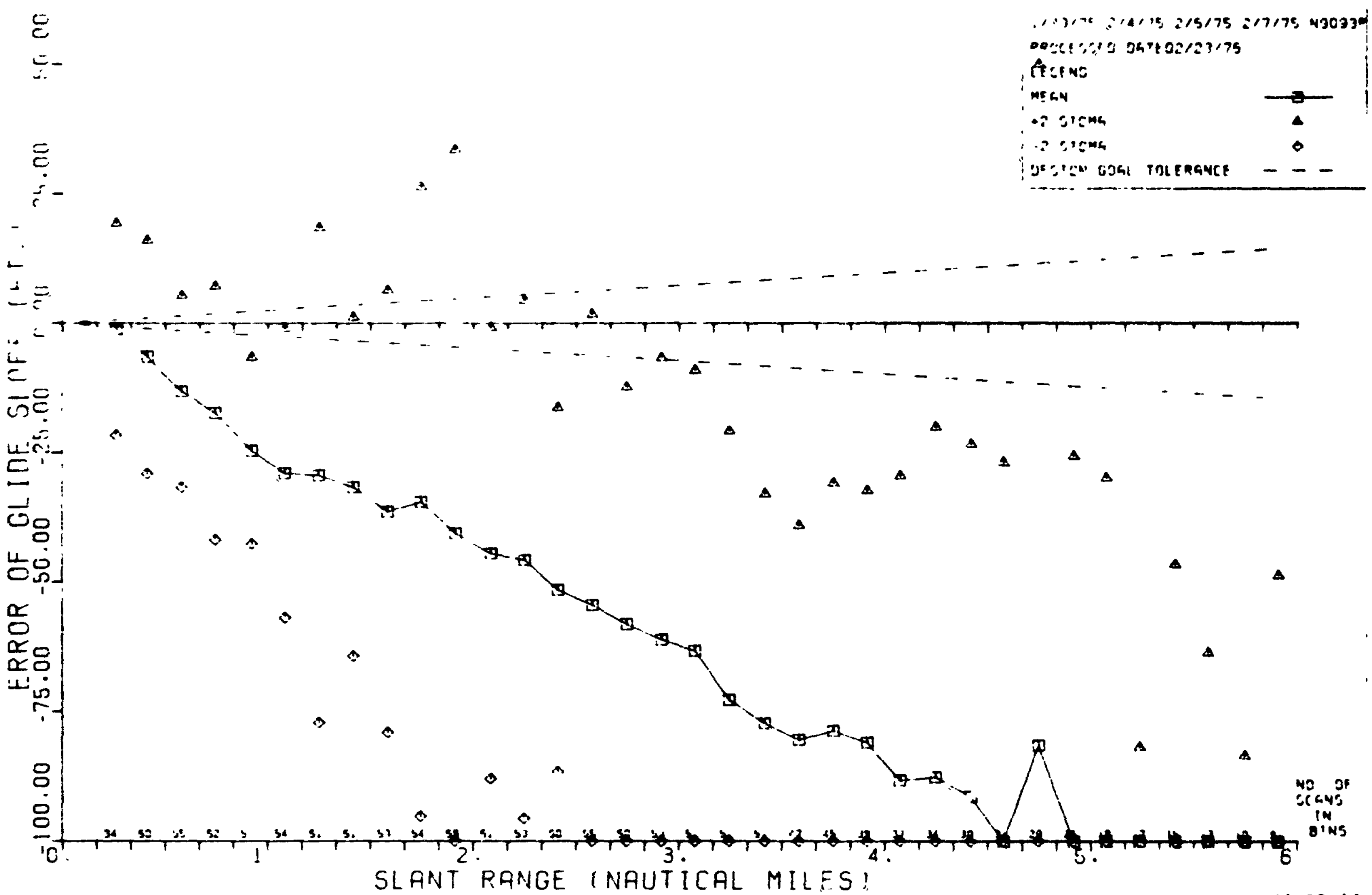


FIGURE 45. ALL FLIGHT PERIODS OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET



76-20-46.

FIGURE 46. ALL FLIGHT PERIODS OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET

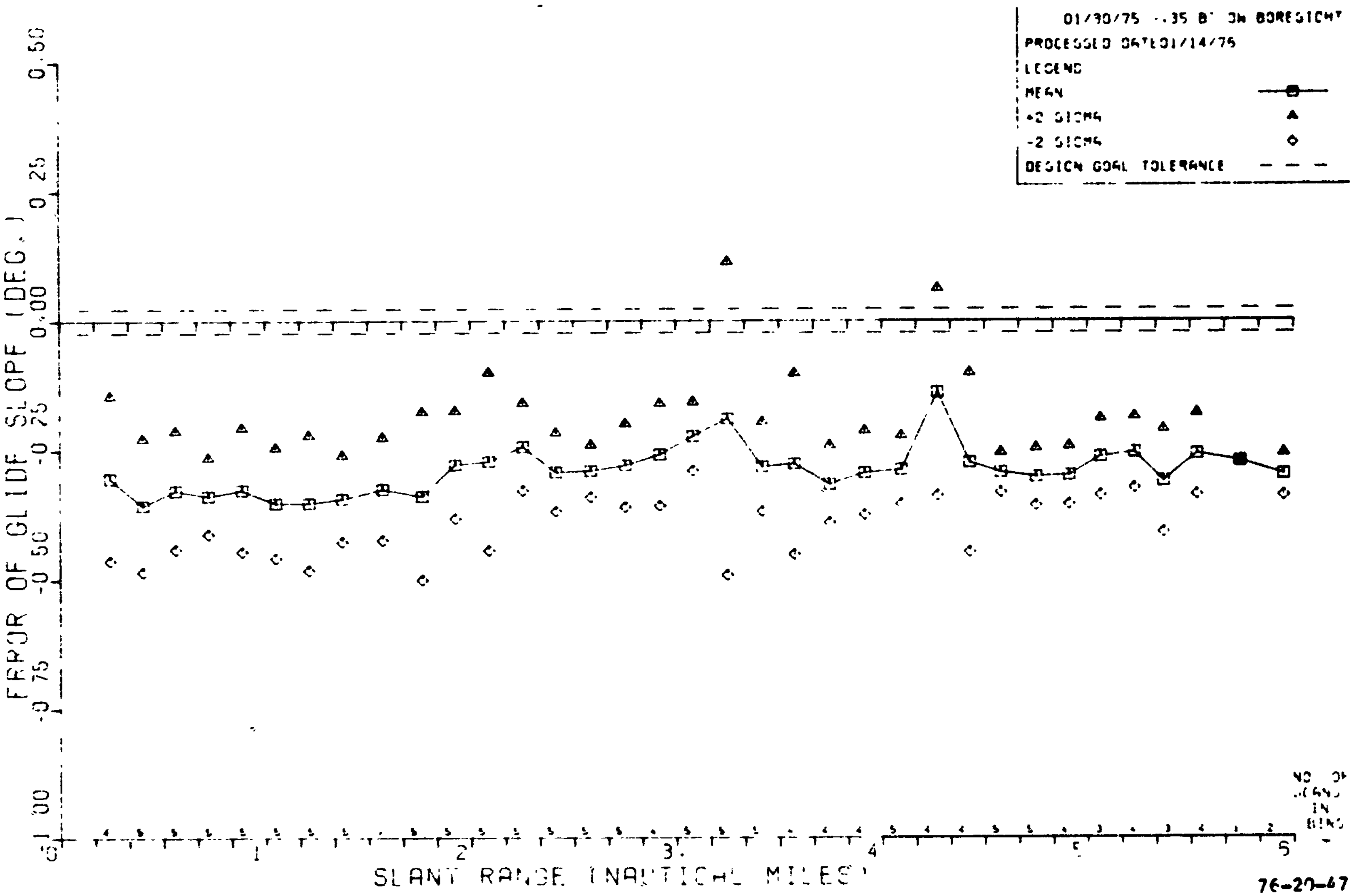


FIGURE 47. FLIGHT PERIOD OF N-377 ON THE 0.35° BELOW THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

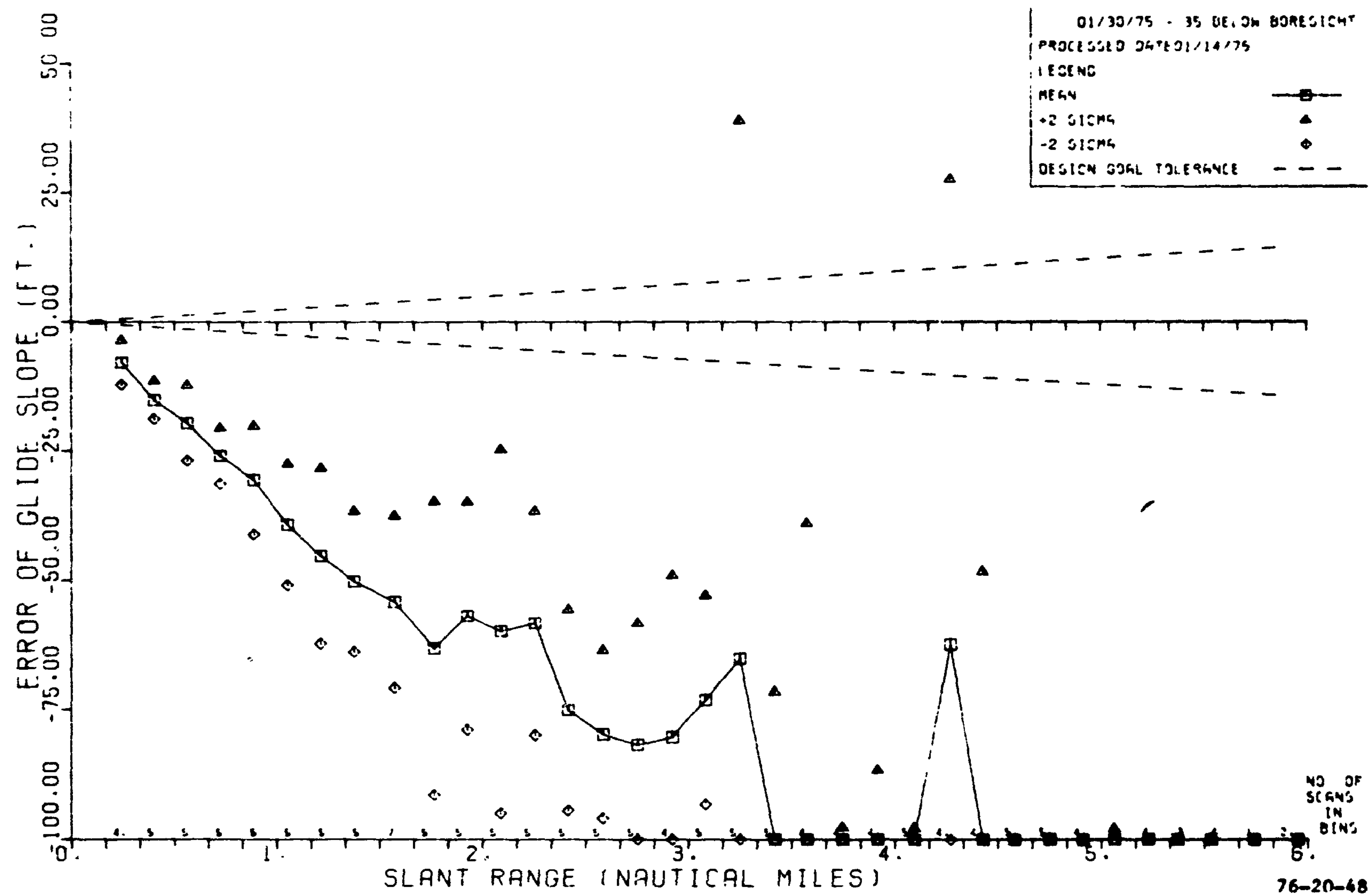


FIGURE 48. FLIGHT PERIOD OF N-377 ON THE 0.35° BELOW THE 3° ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET

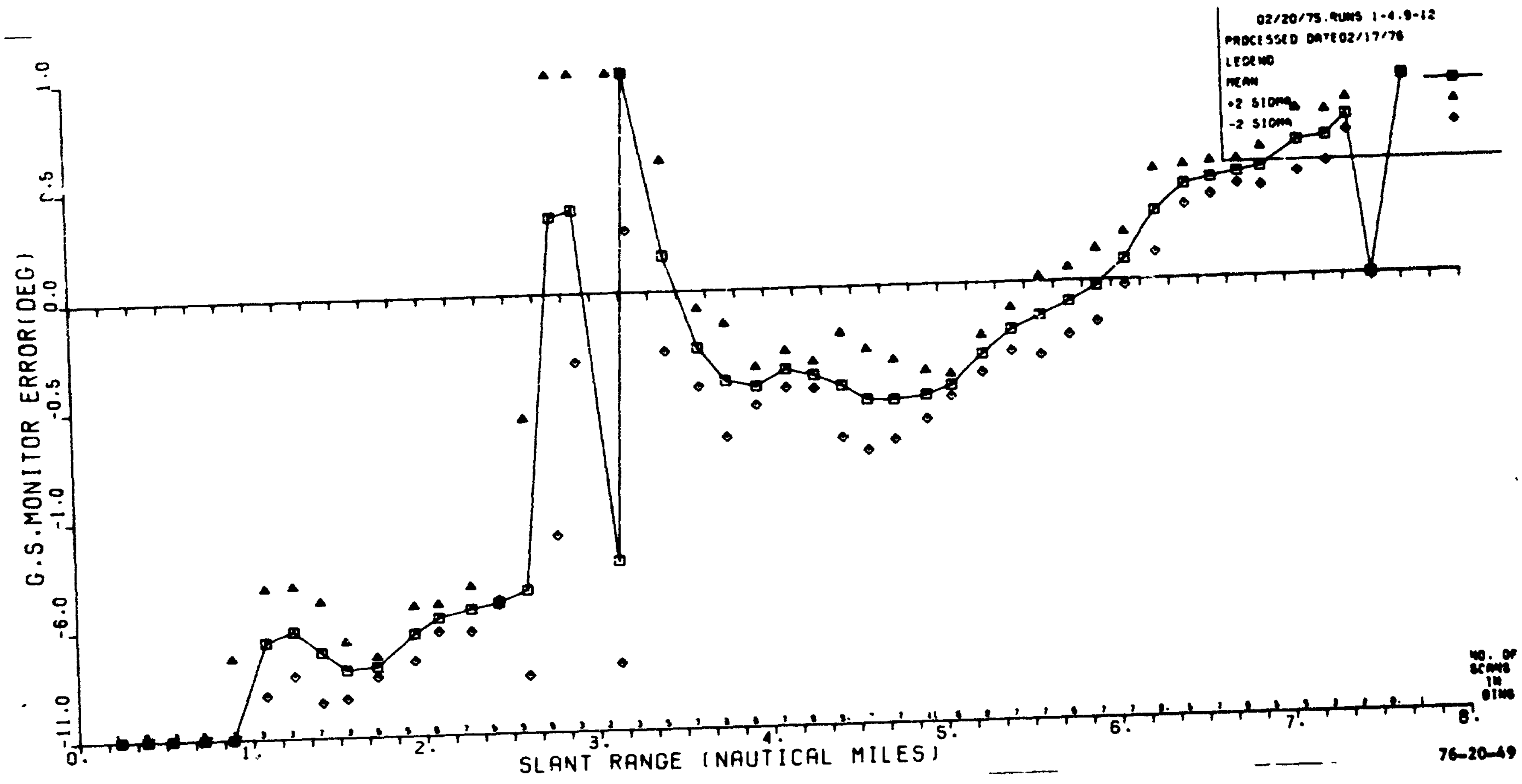


FIGURE 49. FLIGHT PERIOD OF N-377 ON THE 1508 FEET LEVEL ALTITUDE FLIGHT ALONG THE 3° FINAL APPROACH PATH IN TERMS OF DEGREE OFFSET

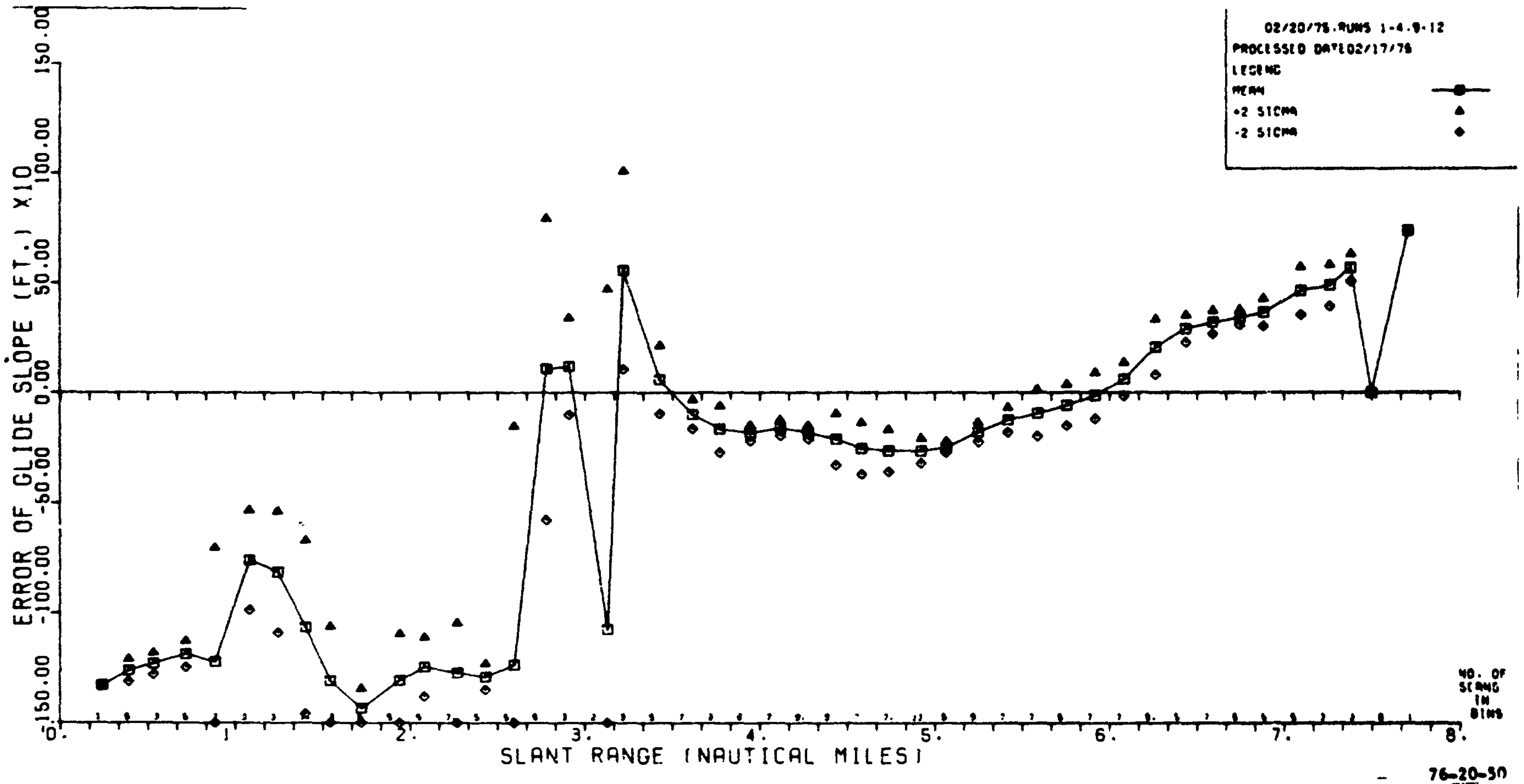


FIGURE 50. FLIGHT PERIOD OF N-377 ON THE 1508 FEET LEVEL ALTITUDE FLIGHT ALONG THE 3° FINAL APPROACH PATH IN TERMS OF ALTITUDE FEET OFFSET

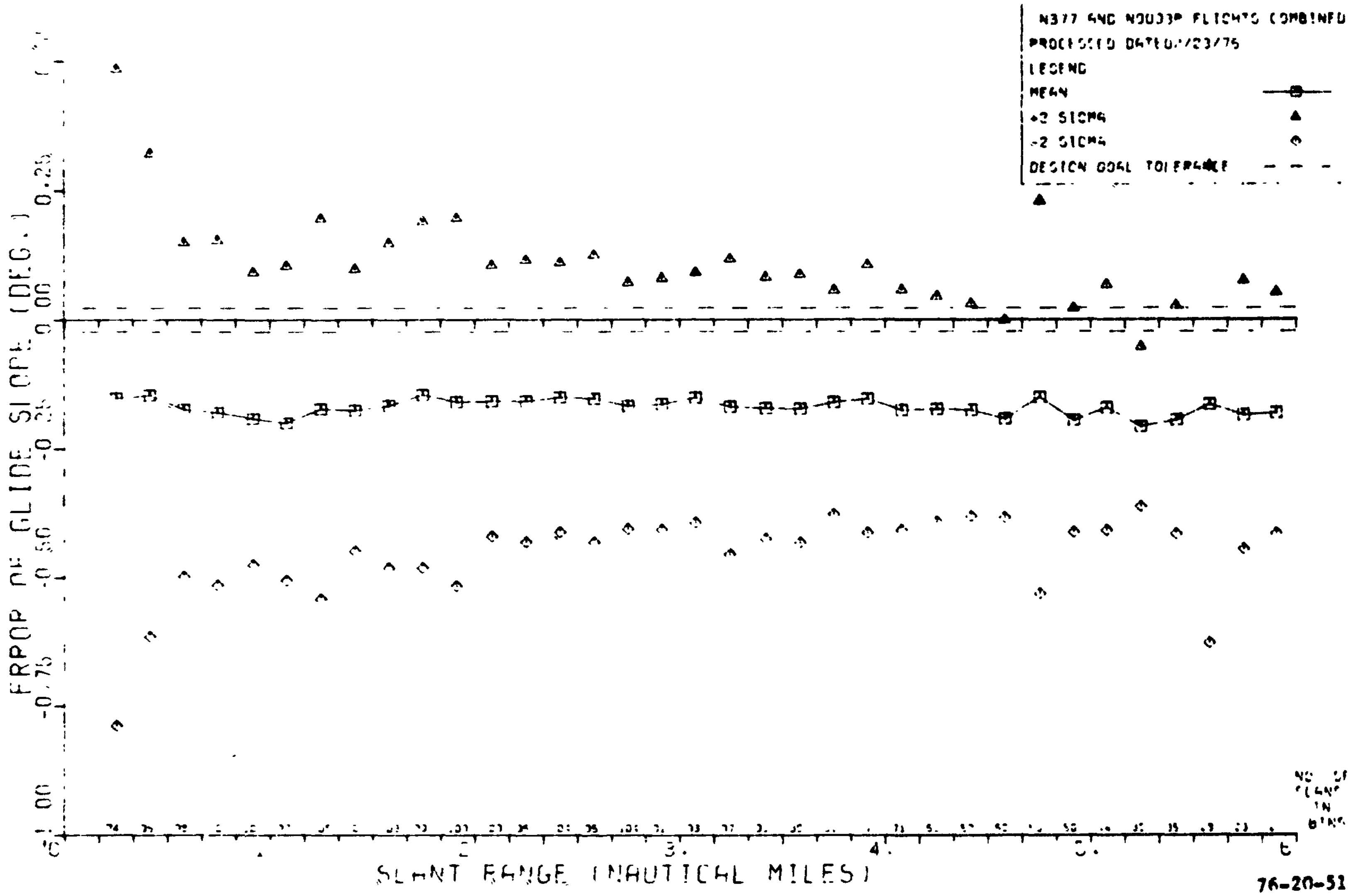


FIGURE 51. ALL FLIGHT PERIODS OF N-377 AND N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET

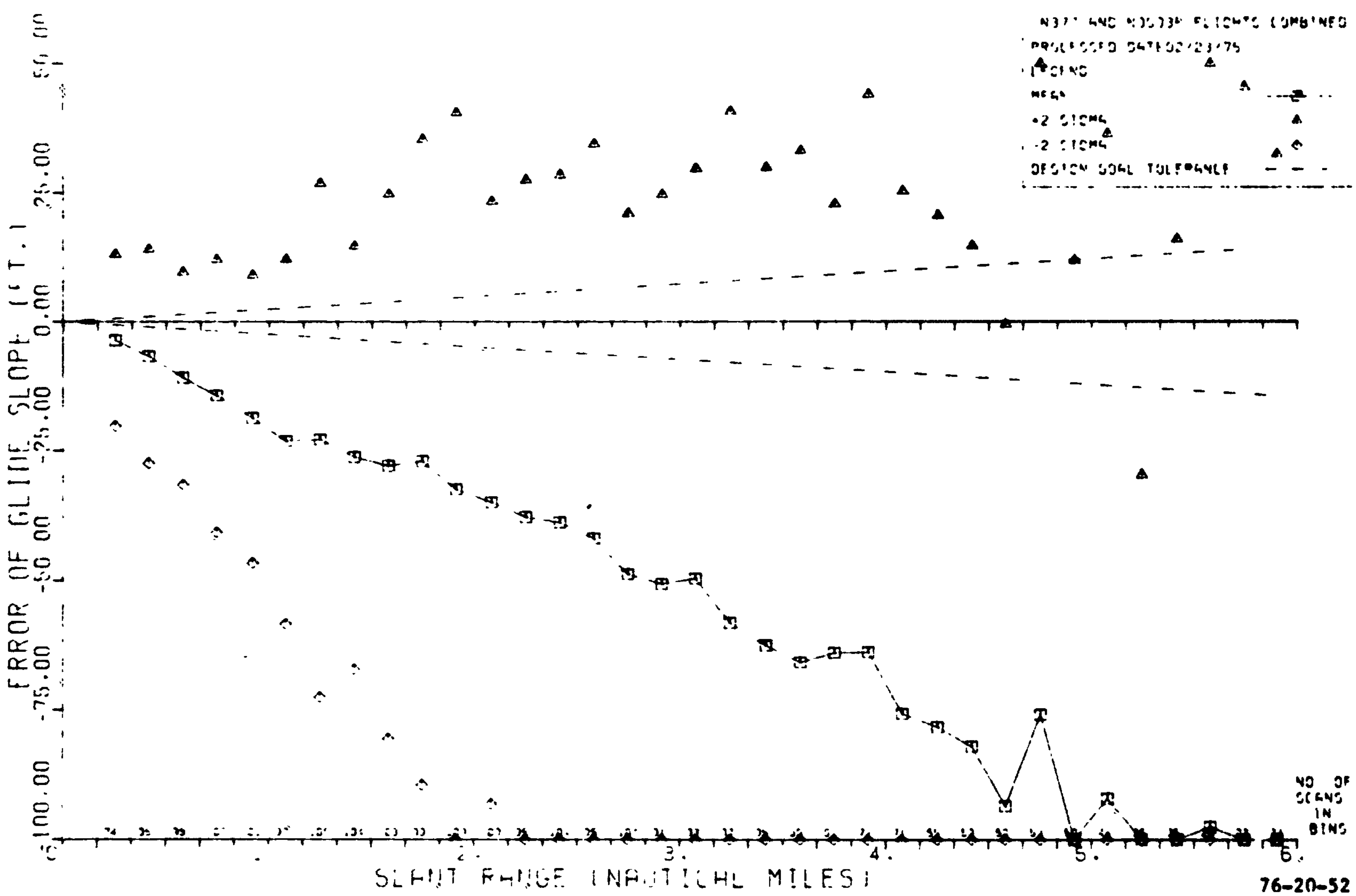


FIGURE 52. ALL FLIGHT PERIODS ON N-377 AND N-9093P ON THE 3°ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET

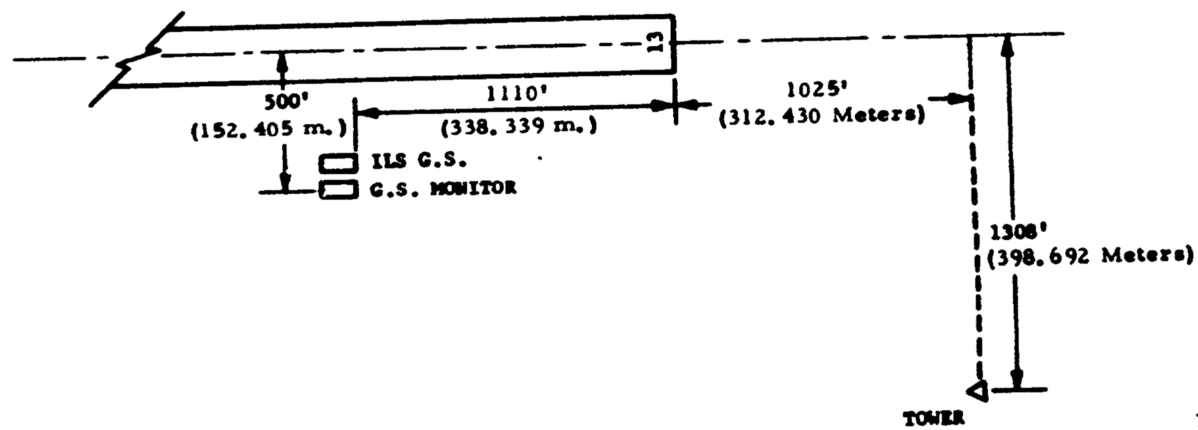


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FIGURE 53. THE RELATIVE LOCATIONS OF THE MONOPULSE ANTENNA AND THE FIXED TARGET/TOWER.

APPENDIX A

SAMPLE PLOTS OF REDUCED DATA SHOWING THE INDIVIDUAL FLIGHT TRACKS AND THE RELATED ERROR DATA

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (continued)

APPENDIX A

SAMPLE PLOTS OF REDUCED DATA SHOWING THE INDIVIDUAL FLIGHT TRACKS AND THE RELATED ERROR DATA

This appendix contains samples of the flight plots developed in the reduction of the collected data. On the 3° glide path flight's sample plots are shown in figures A-1, A-2, A-3, and A-4. At -0.35° below the 3° glide path flight's sample plots are shown in figures A-5, A-6, A-7, and A-8 (where the boresight line of 0.0° is the flight line). At the level altitude of 1508 feet (459.65348 meters) along the 3° Final Approach Path that intersects this path at the OM, the flight's sample plots are shown in figures A-9, A-10, A-11, and A-12. At the level altitude of 230 feet (70.10630 meters) along the 3° Final Approach Path that intersects this path at the middle marker, the flight's sample plots are shown in figures A-13, A-14, A-15, and A-16.

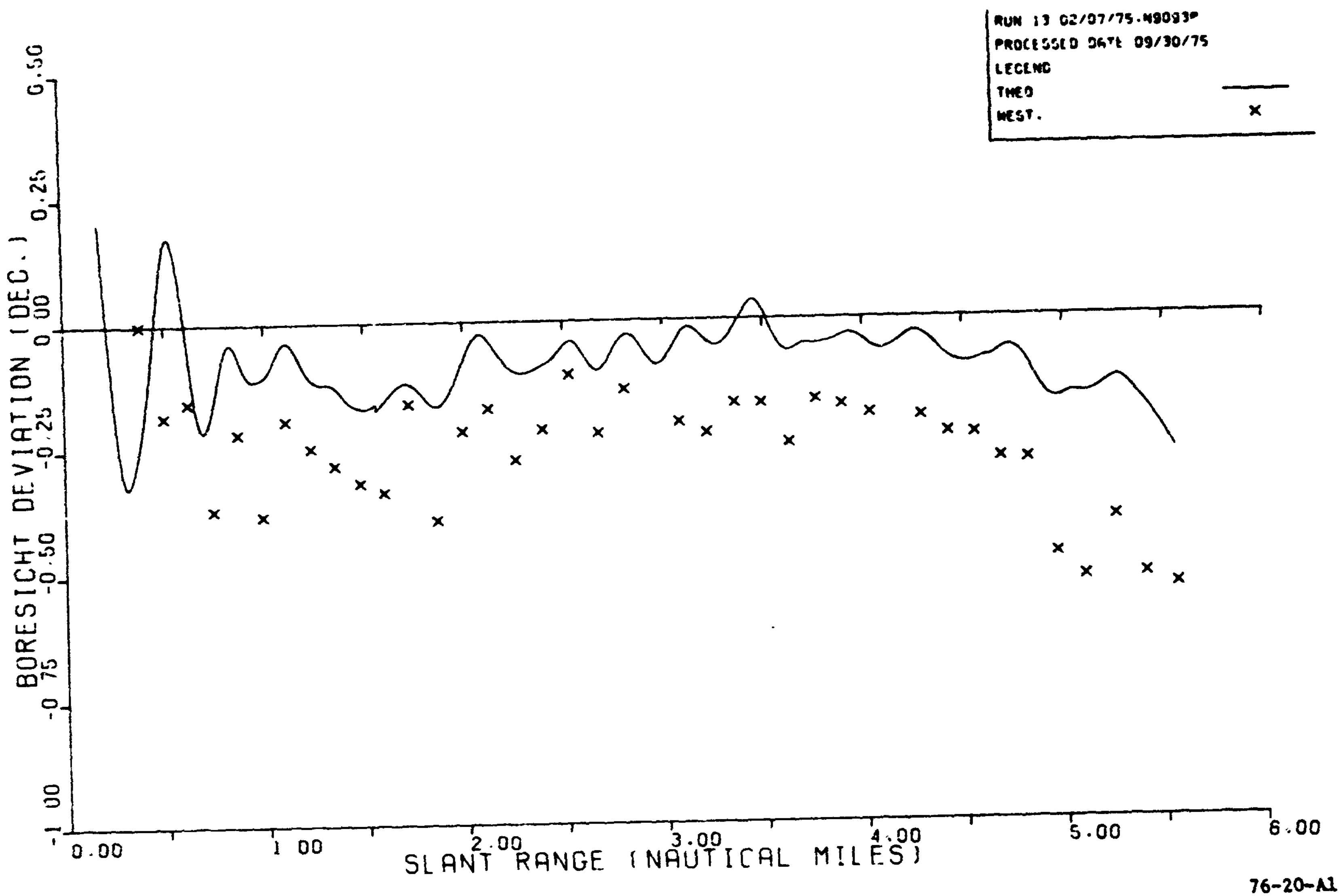
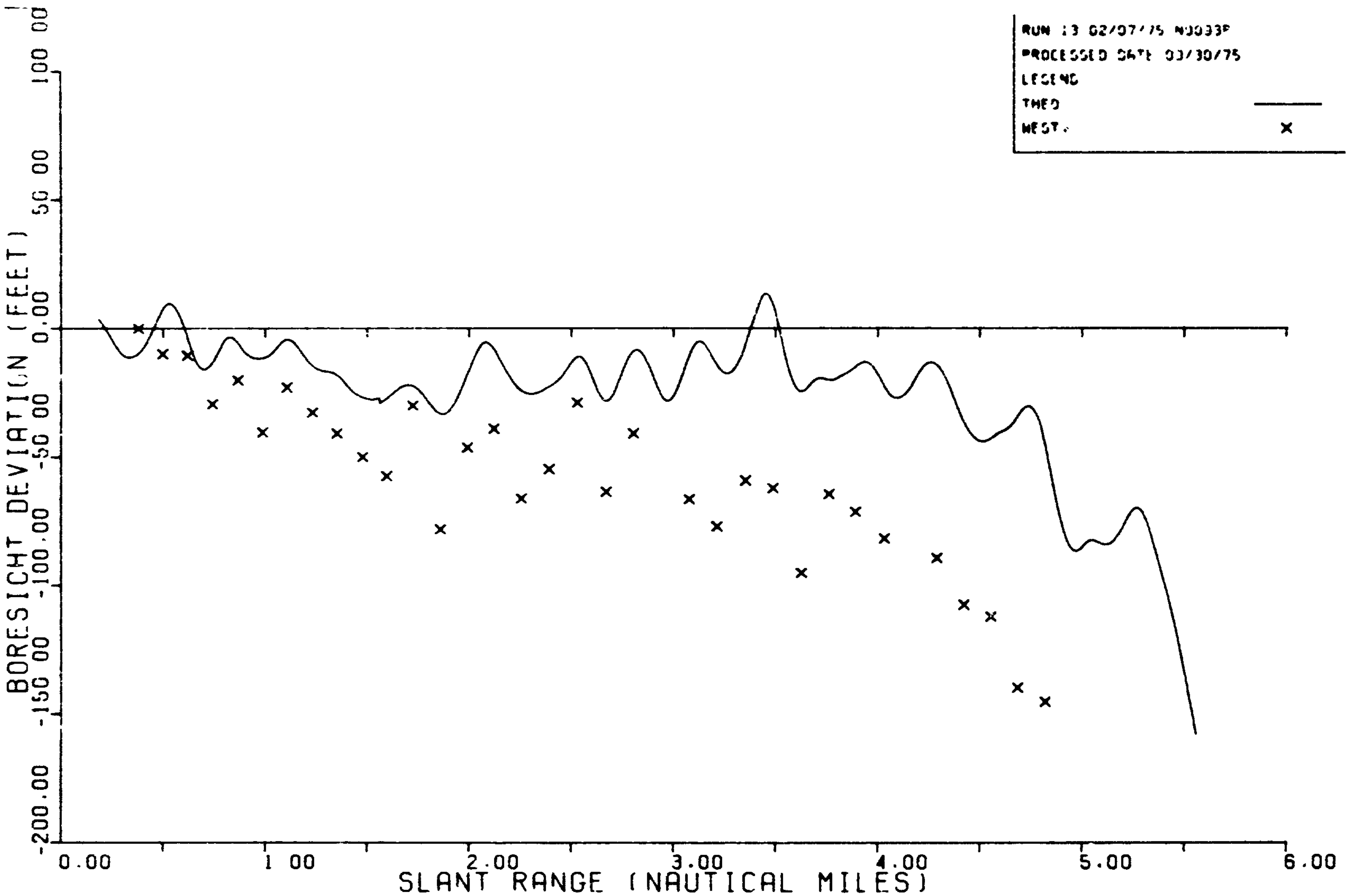
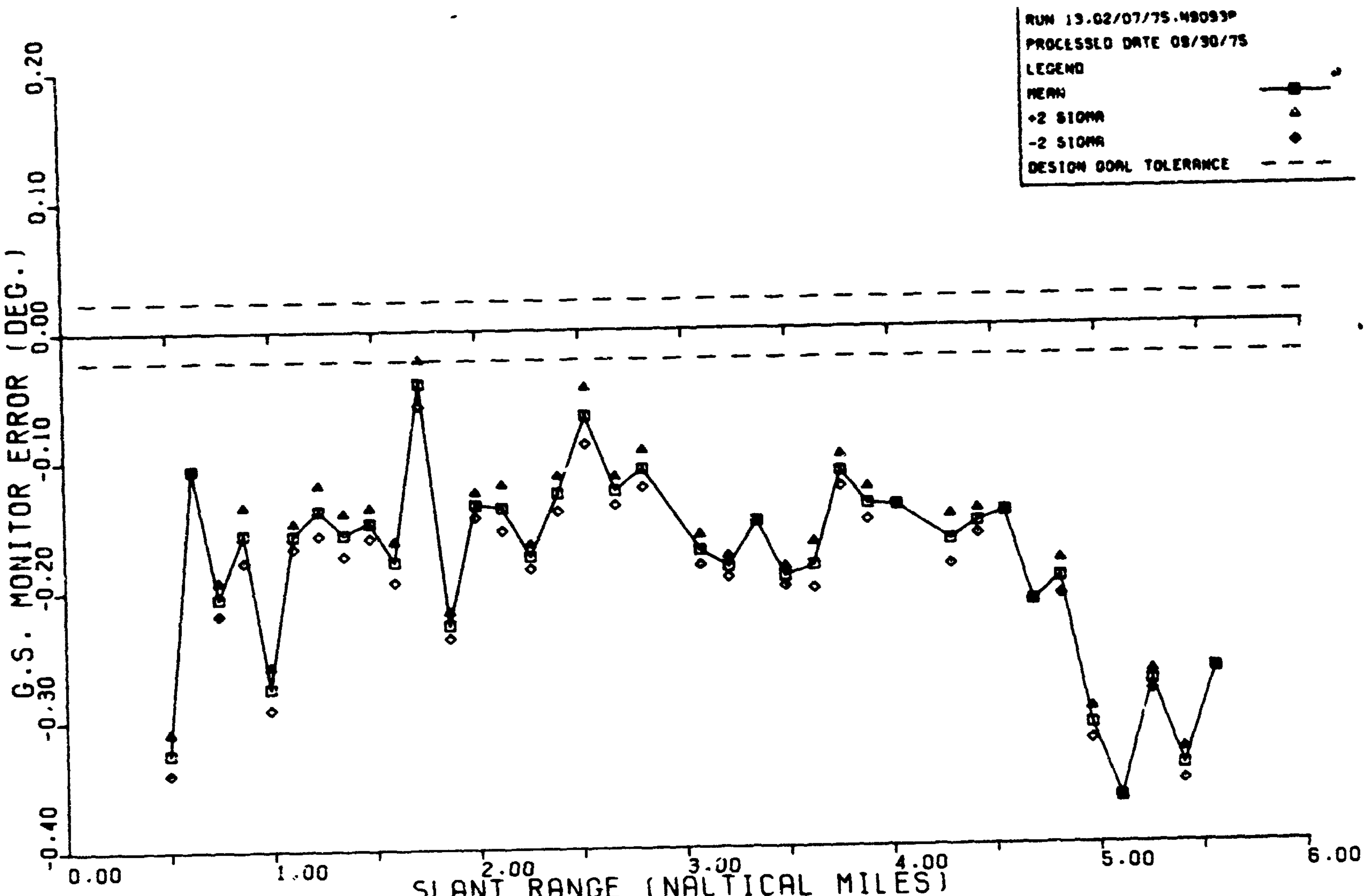


FIGURE A-1. TRACK DATA OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSET FROM THE MONOPULSE ANTENNA'S BORESIGHT.



76-20-A2

FIGURE A-2. TRACK DATA OF N-9093P ON THE 3° ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET FROM THE MONOPULSE ANTENNA'S BORESIGHT



76-20-A3

FIGURE A-3. ERROR DATA IN TERMS OF DEGREE OFFSET FOR N-9093P FLYING THE 3° ILS GLIDE SLOPE

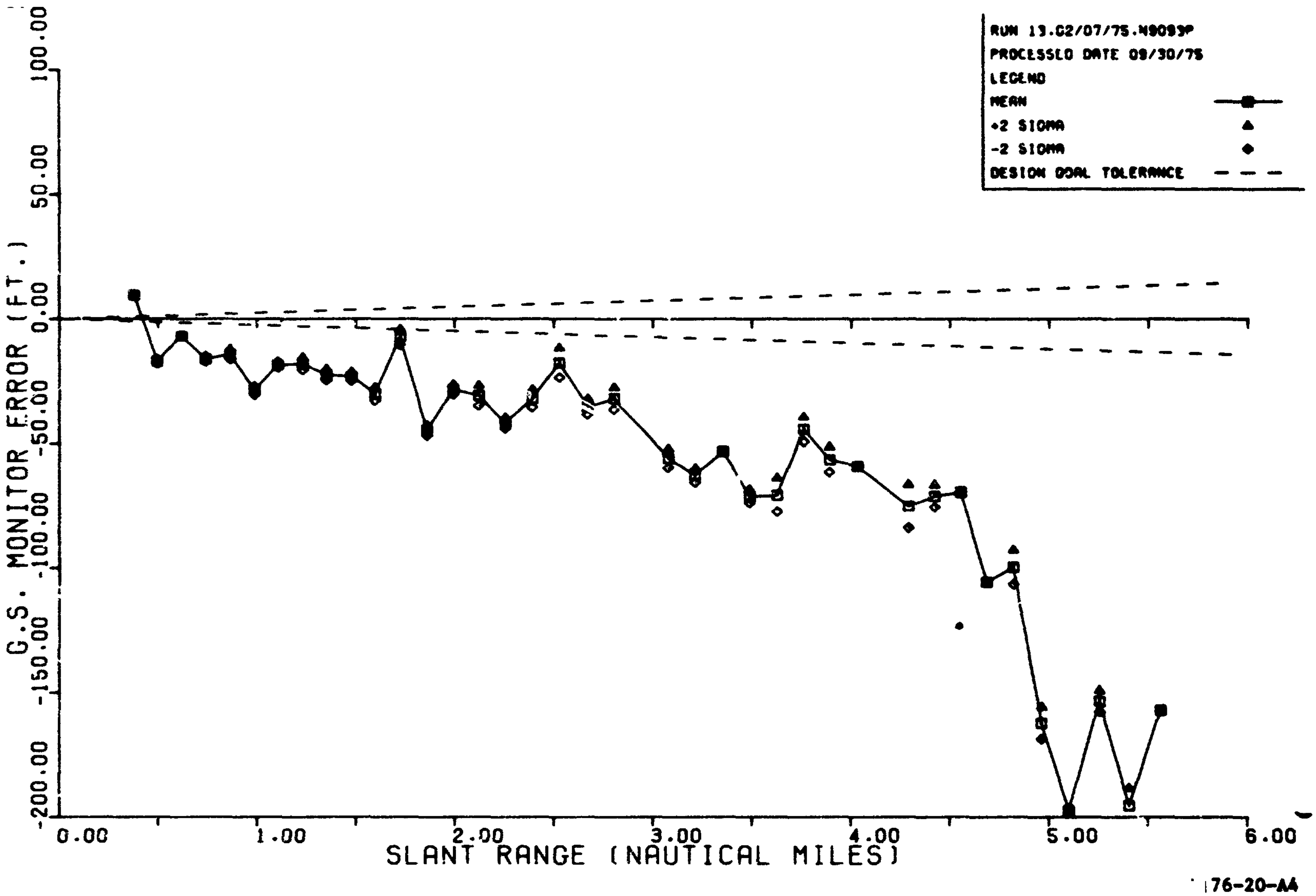
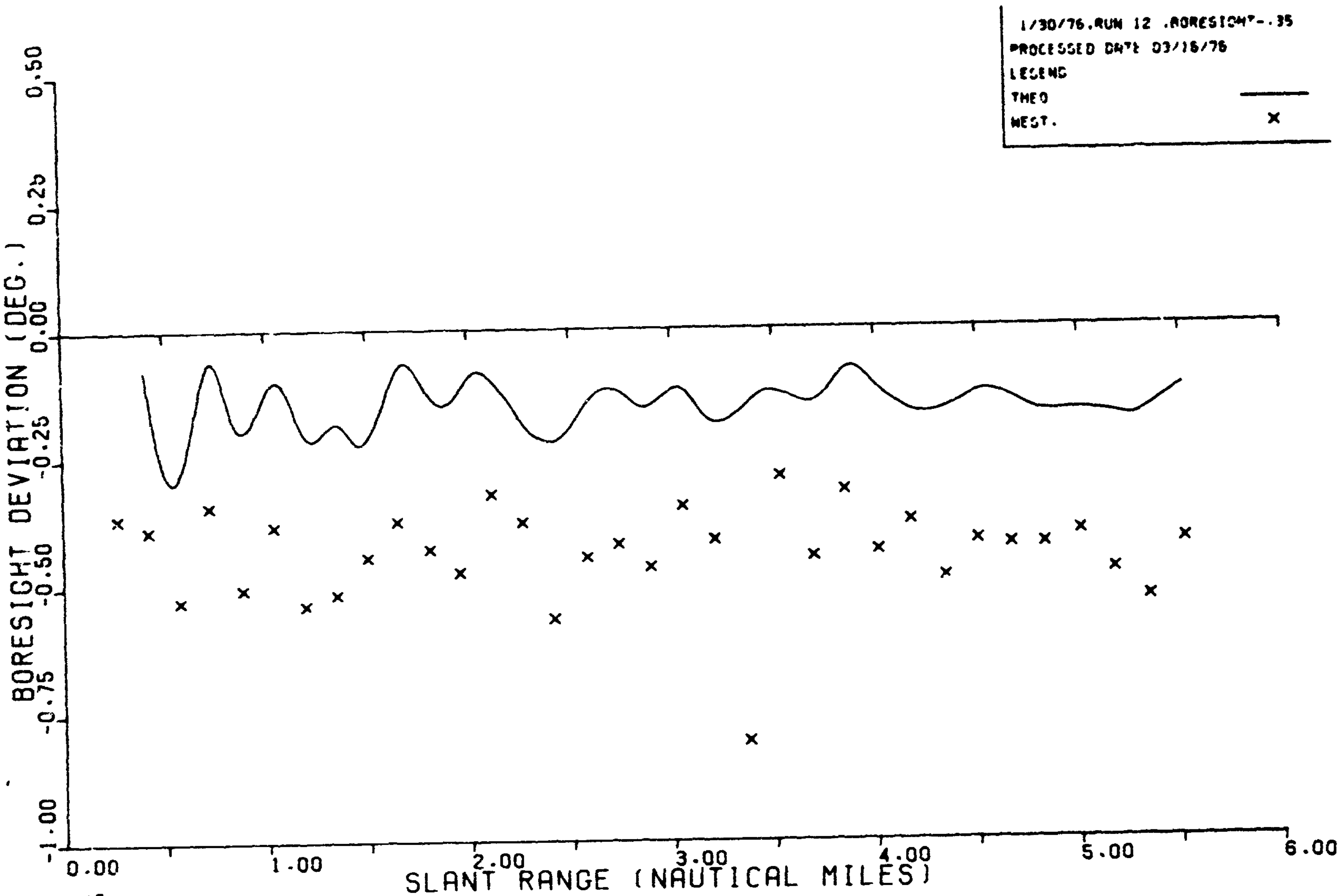


FIGURE A-4. ERROR DATA IN TERMS OF ALTITUDE FEET OFFSET FOR N-9093P FLYING THE 3° ILS GLIDE SLOPE



76-20-A5

FIGURE A-5. TRACK DATA OF N-377 0.35° BELOW THE 3° ILS GLIDE SLOPE IN TERMS OF DEGREE OFFSETS FROM THE FLIGHT LINE

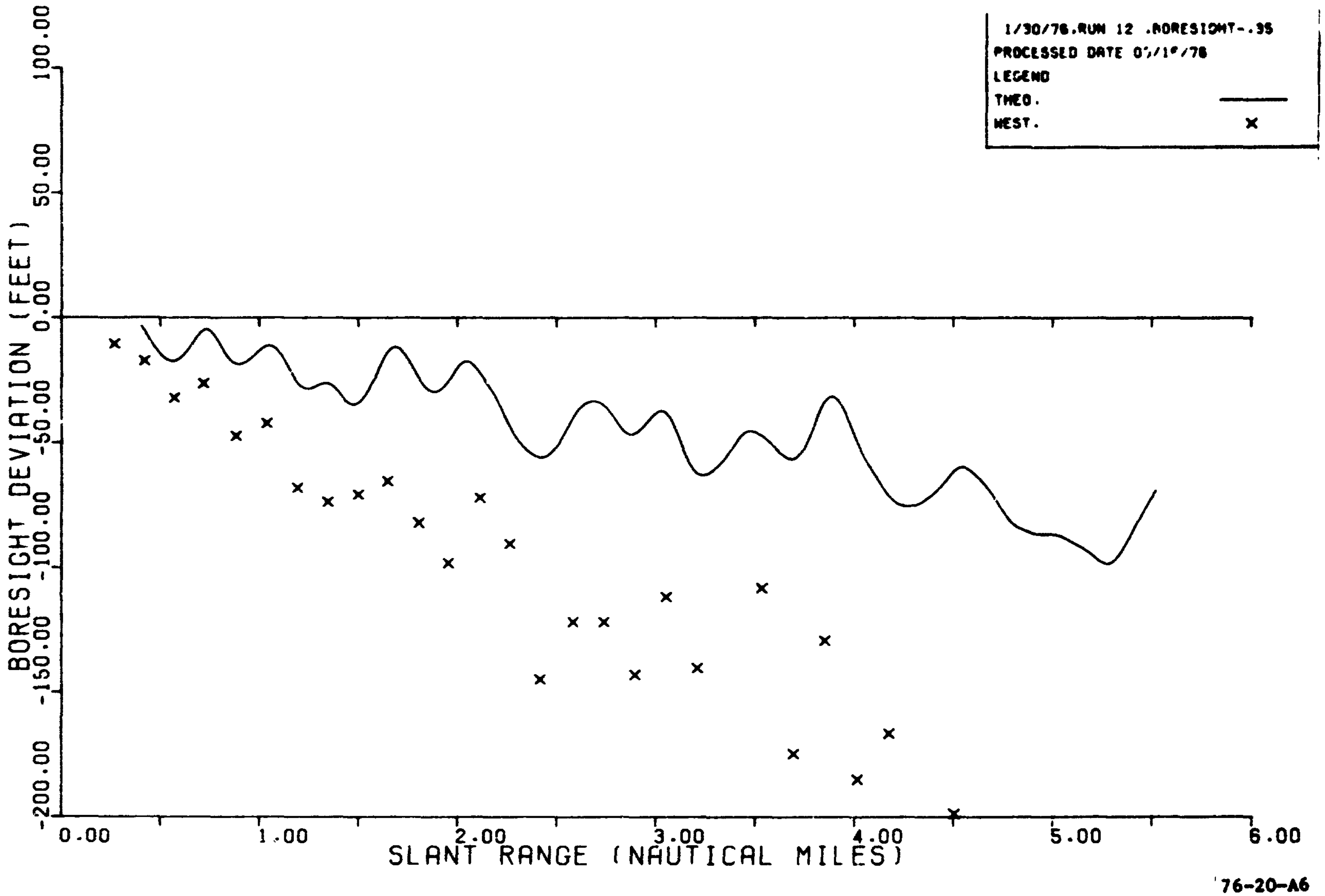


FIGURE A-6. TRACK DATA OF N-377 0.35° BELOW THE 3° ILS GLIDE SLOPE IN TERMS OF ALTITUDE FEET OFFSET FROM THE FLIGHT LINE

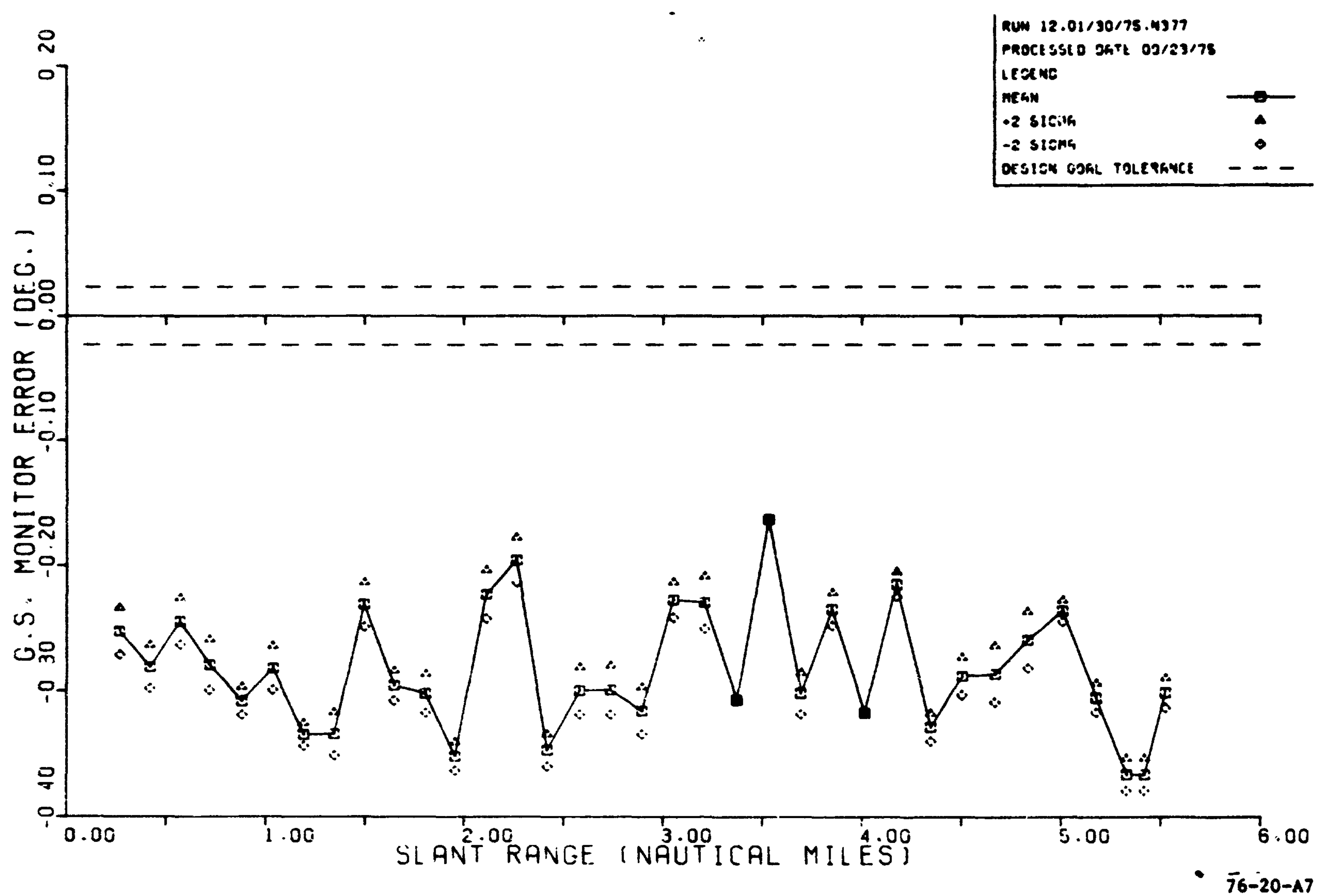


FIGURE A-7. ERROR DATA IN TERMS OF DEGREES OFFSET FOR N-377 FLYING THE 0.35° BELOW THE 3° ILS GLIDE SLOPE

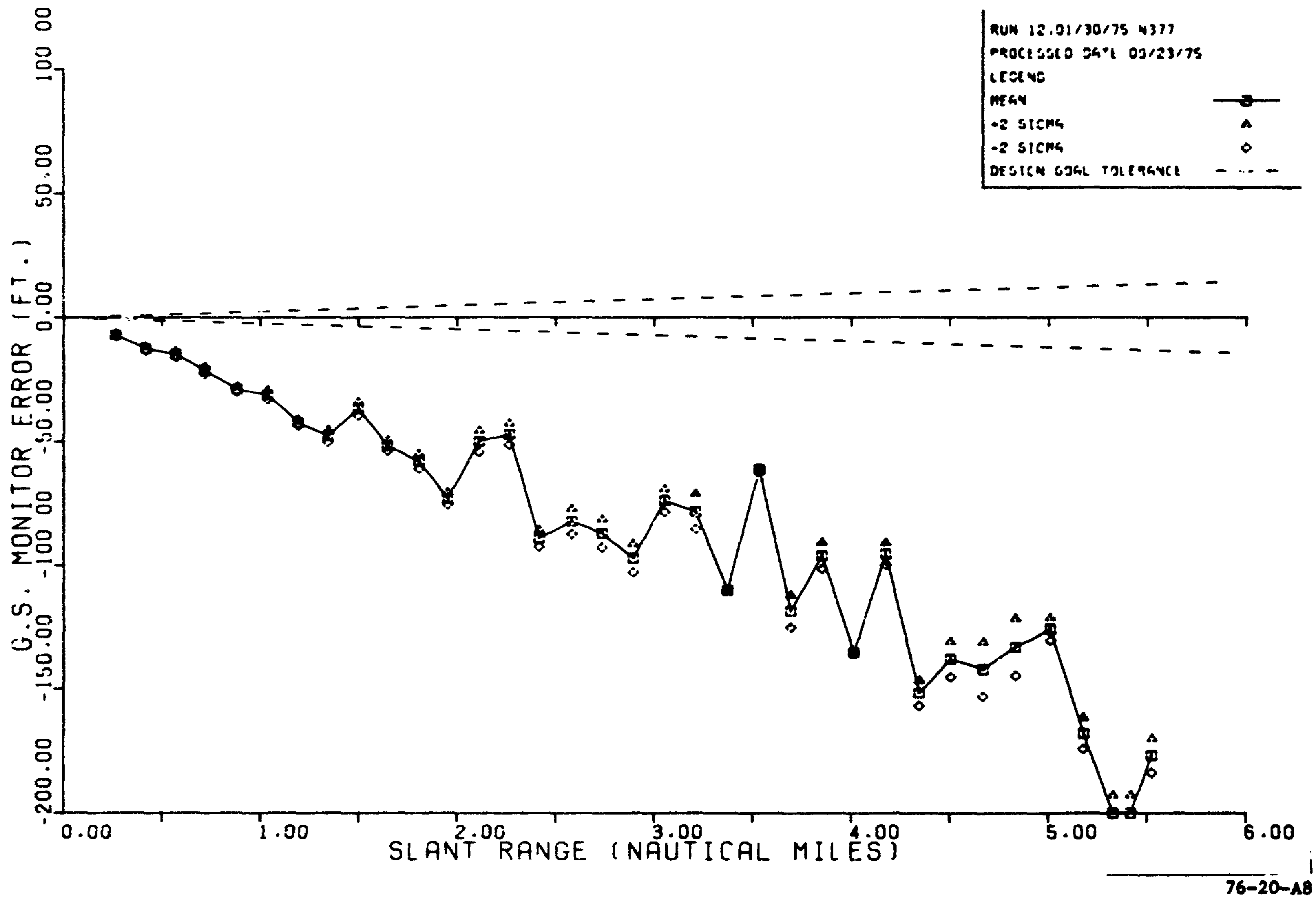


FIGURE A-8. ERROR DATA IN TERMS OF FEET OFFSET FOR N-377 FLYING THE 0.35° BELOW THE 3° ILS GLIDE SLOPE

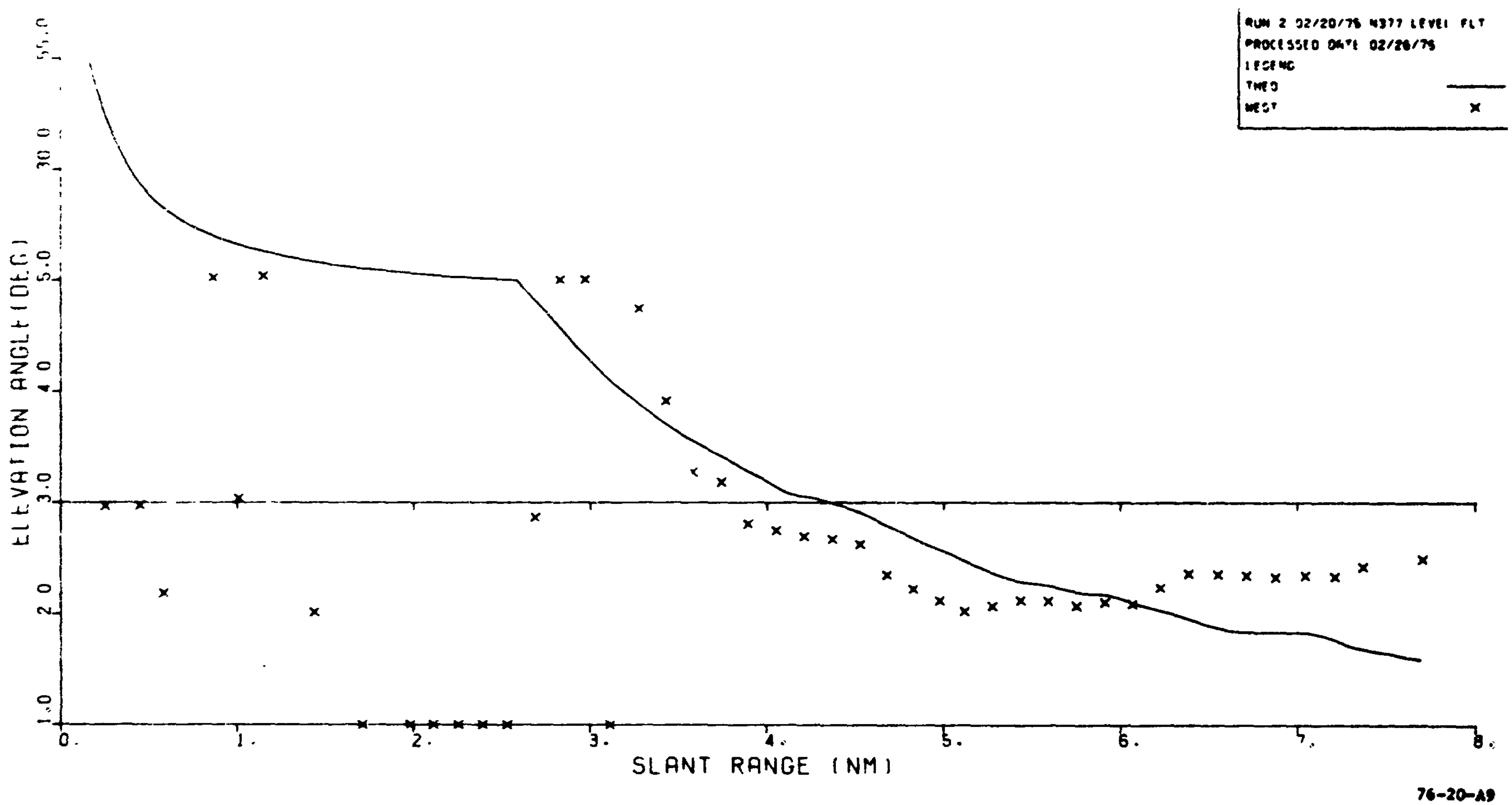
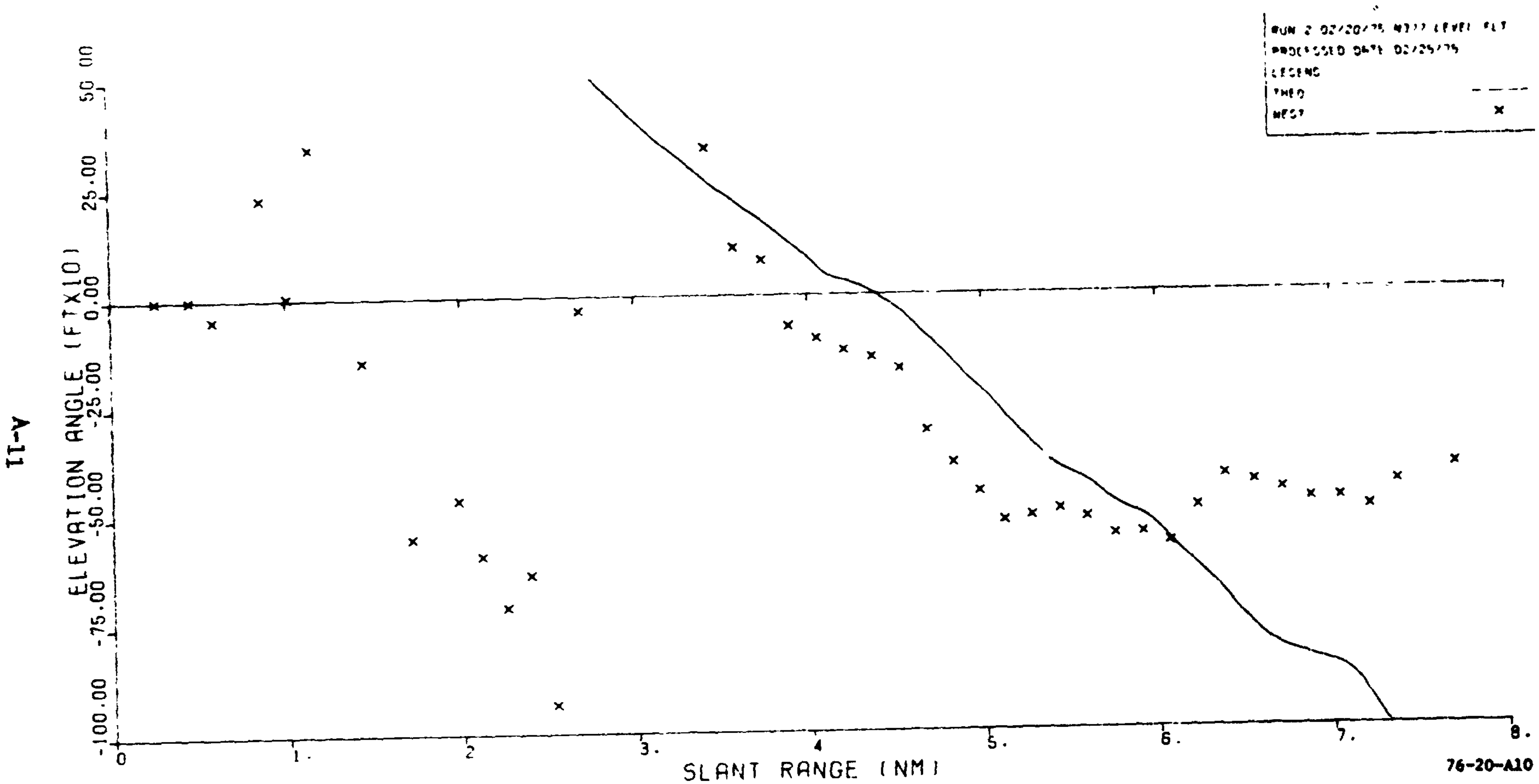
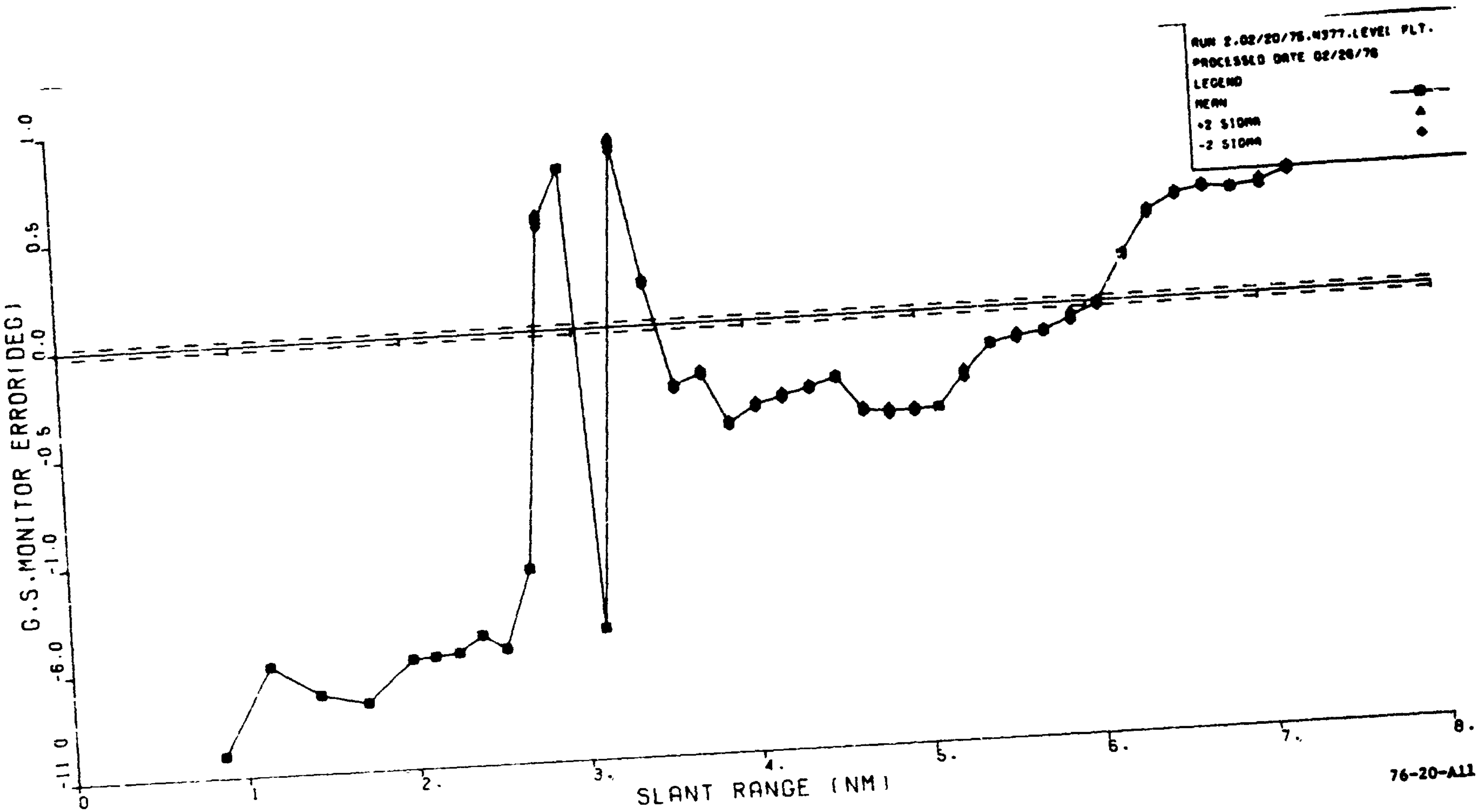


FIGURE A-9. TRACK DATA OF N-377 ON THE 1508 FEET LEVEL ALTITUDE FLIGHT ALONG THE 3° FINAL APPROACH PATH IN TERMS OF DEGREE OFFSET

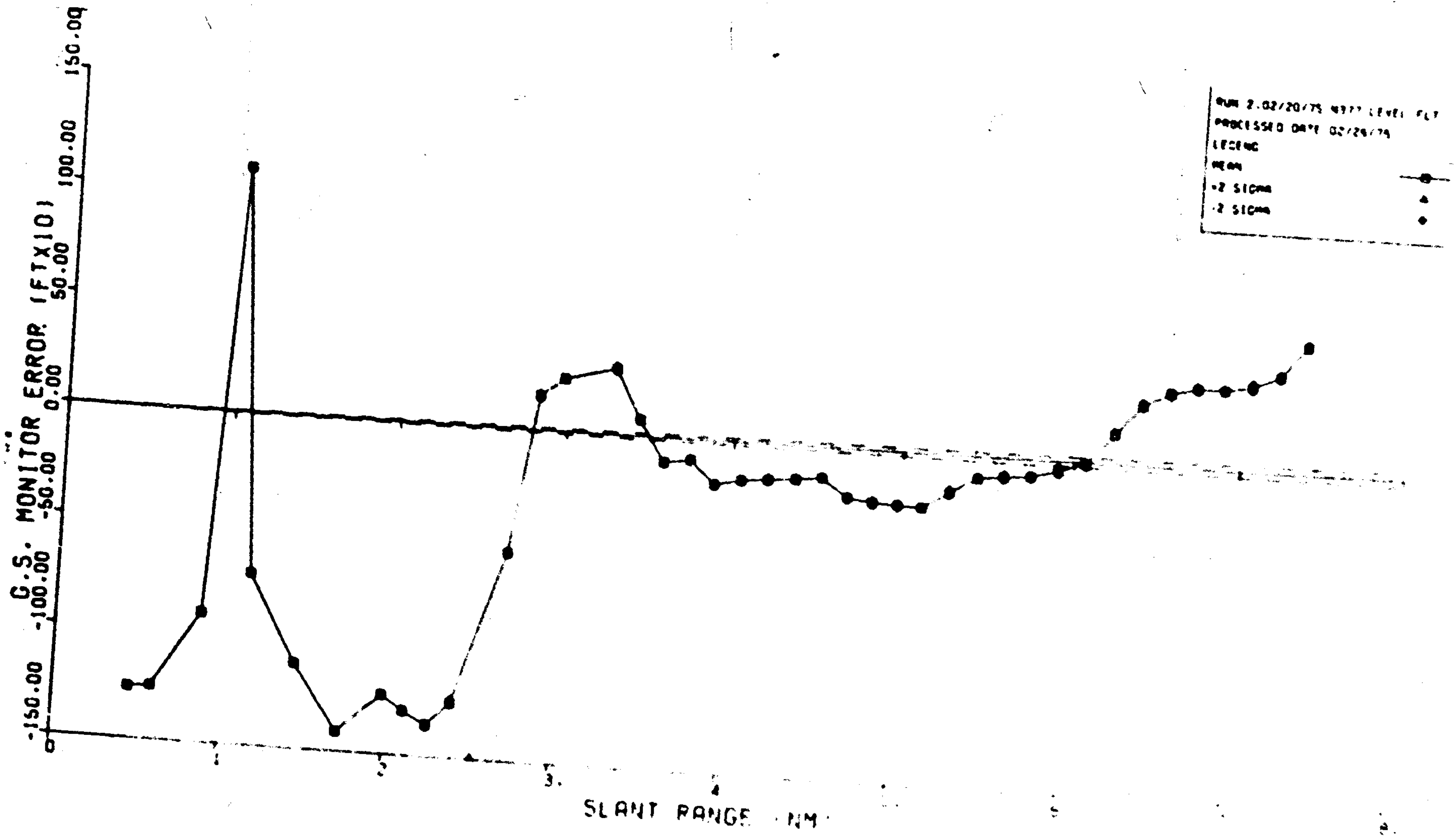


76-20-A10

FIGURE A-10. TRACK DATA OF N-377 ON THE 1508 FEET LEVEL ALTITUDE FLIGHT ALONG THE 3° FINAL APPROACH PATH IN TERMS OF ALTITUDE FEET OFFSET

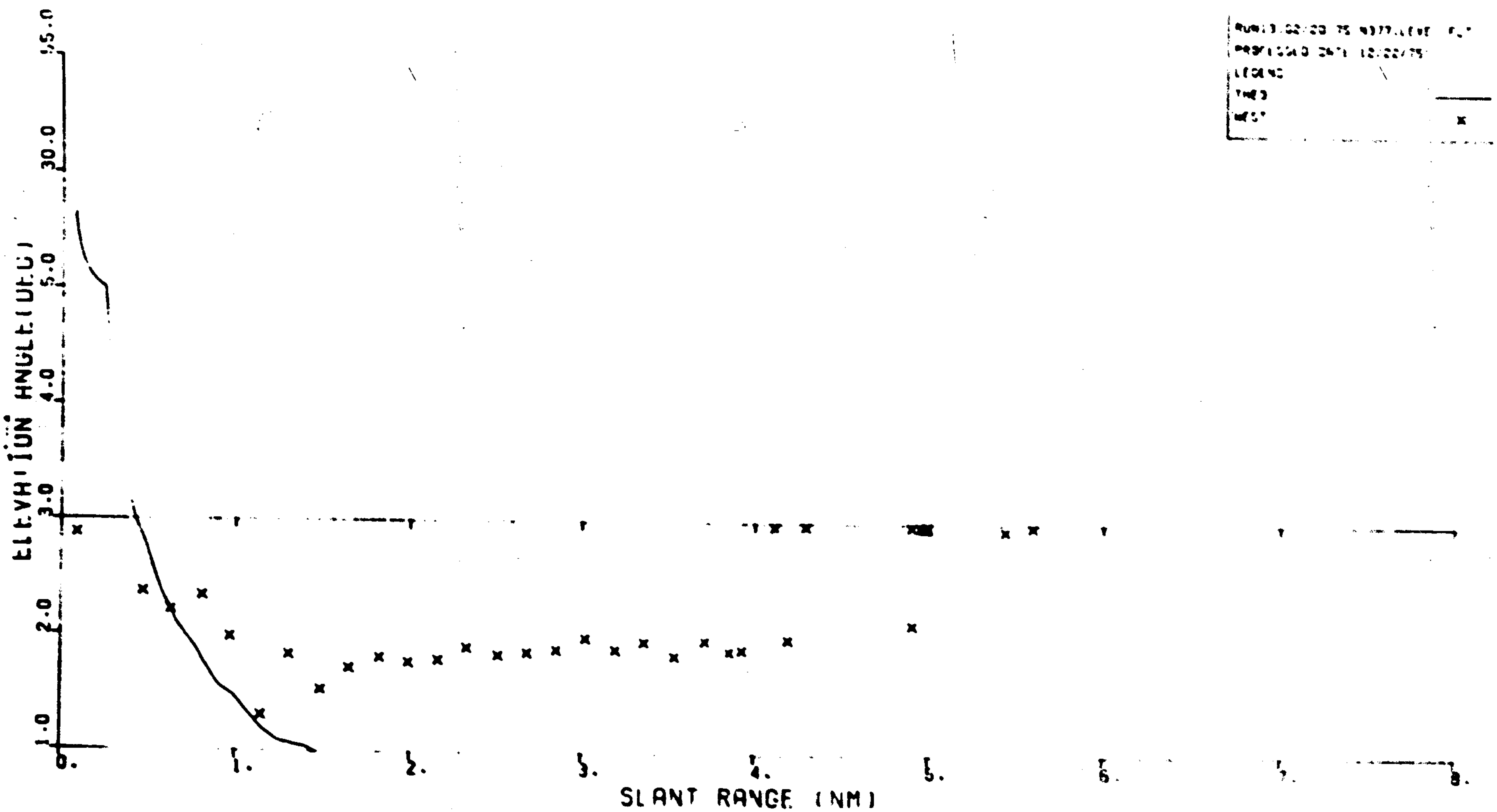


FIGURF A-11. ERROR DATA IN TERMS OF DEGREE OFFSET FOR N-377 ON THE 1508 FEET ALTITUDE FLIGHT PATH ALONG THE 3 ° FINAL APPROACH PATH



76-20-A12

FIGURE A-12. ERROR DATA IN TERMS OF ALTITUDE FEET OFFSET FOR N-377 ON THE 1508 FEET LEVEL ALTITUDE FLIGHT PATH ALONG THE 3° FINAL APPROACH PATH



76-20-A13

FIGURE A-13. TRACK DATA OF N-377 ON THE 230 FEET LEVEL ALTITUDE FLIGHT ALONG THE 3° FINAL APPROACH PATH IN TERMS OF DEGREE OFFSET

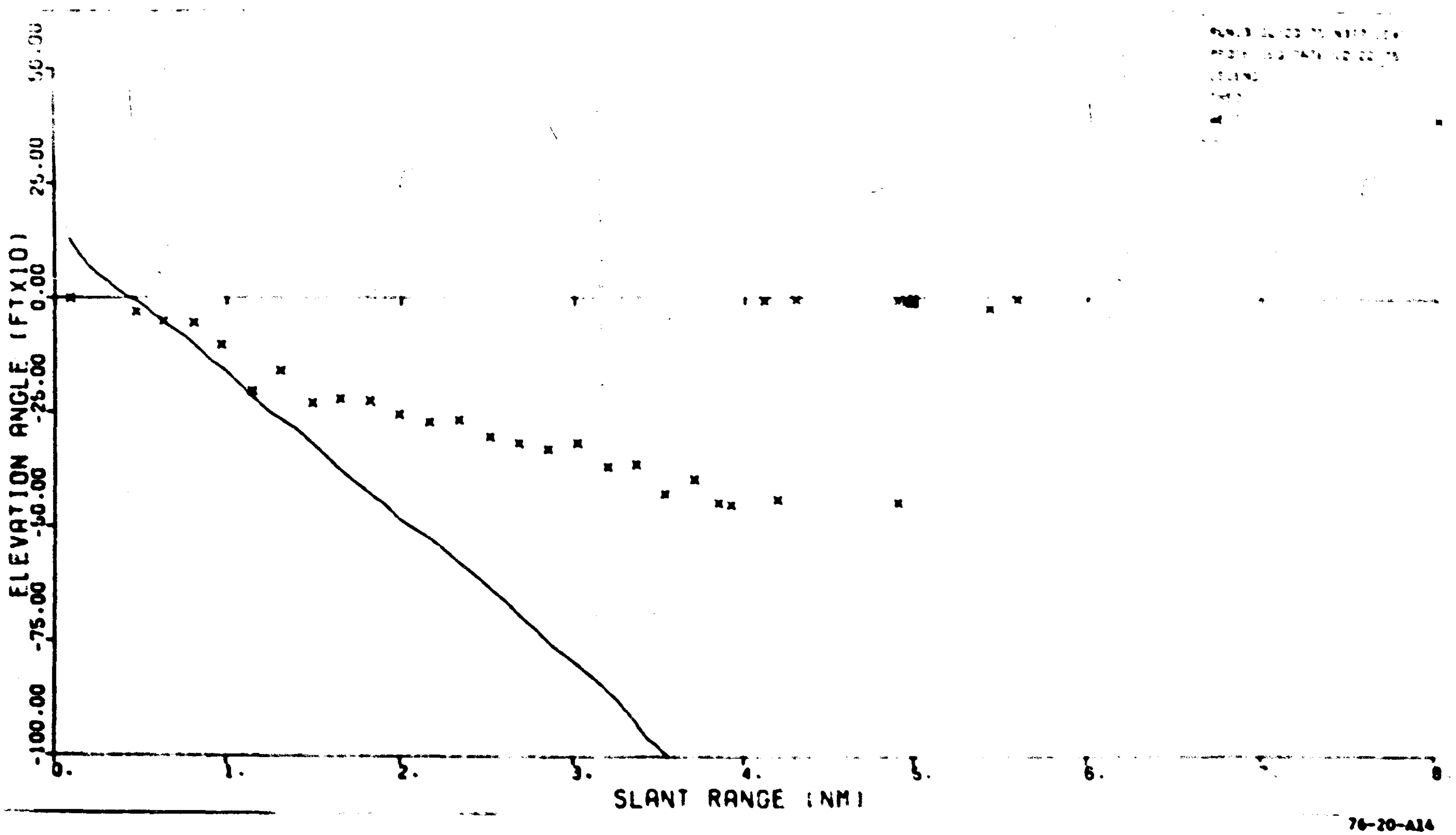


FIGURE A-14. TRACK DATA OF N-377 ON THE 230 FEET LEVEL ALTITUDE FLIGHT ALONG THE 3° FINAL APPROACH PATH IN TERMS OF ALTITUDE FEET OFFSET

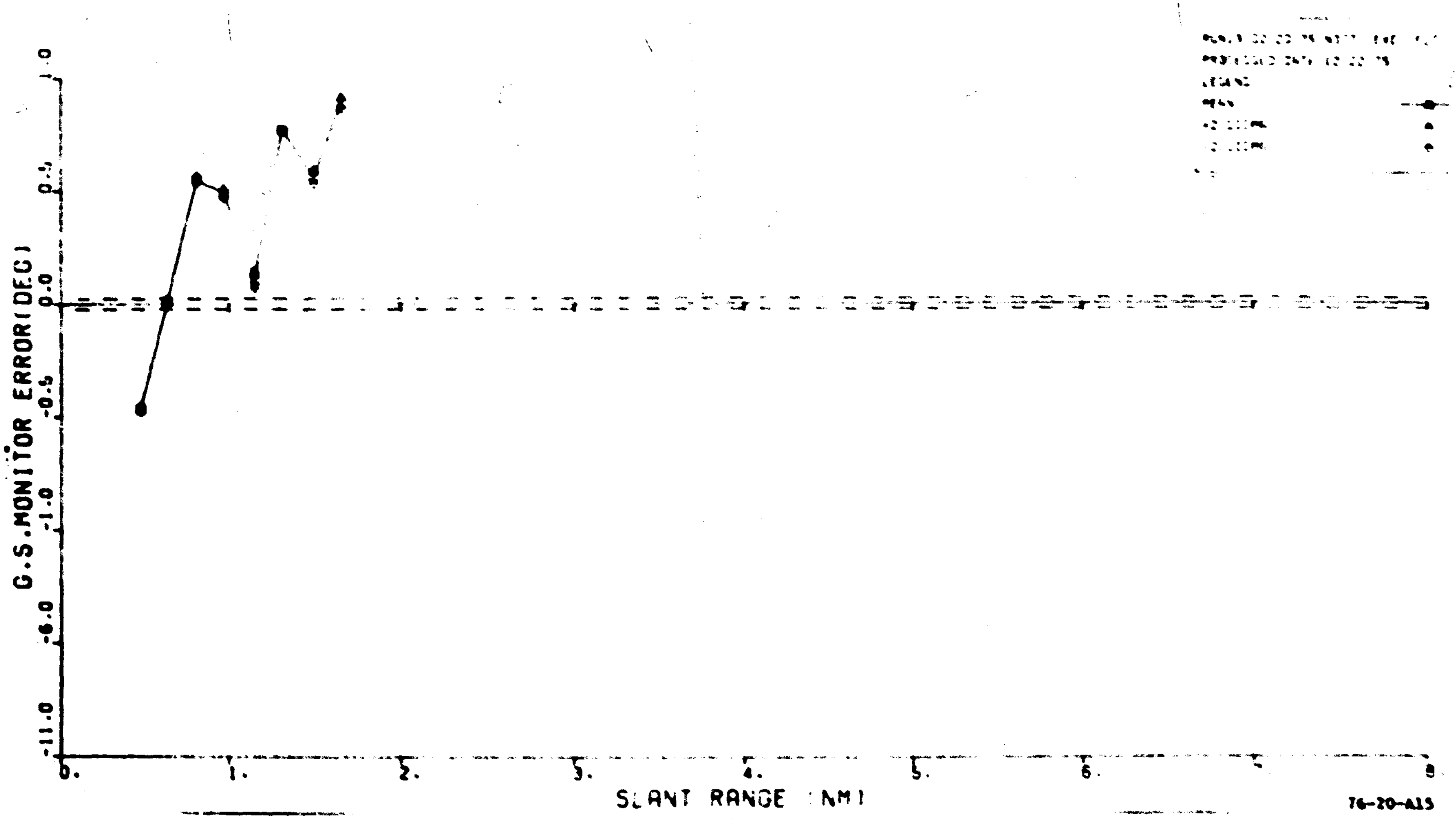


FIGURE A-15. ERROR DATA IN TERMS OF DEGREE OFFSET FOR N-377 FLYING THE 230 FEET LEVEL ALTITUDE FLIGHT PATH ALONG THE 3° FINAL APPROACH PATH

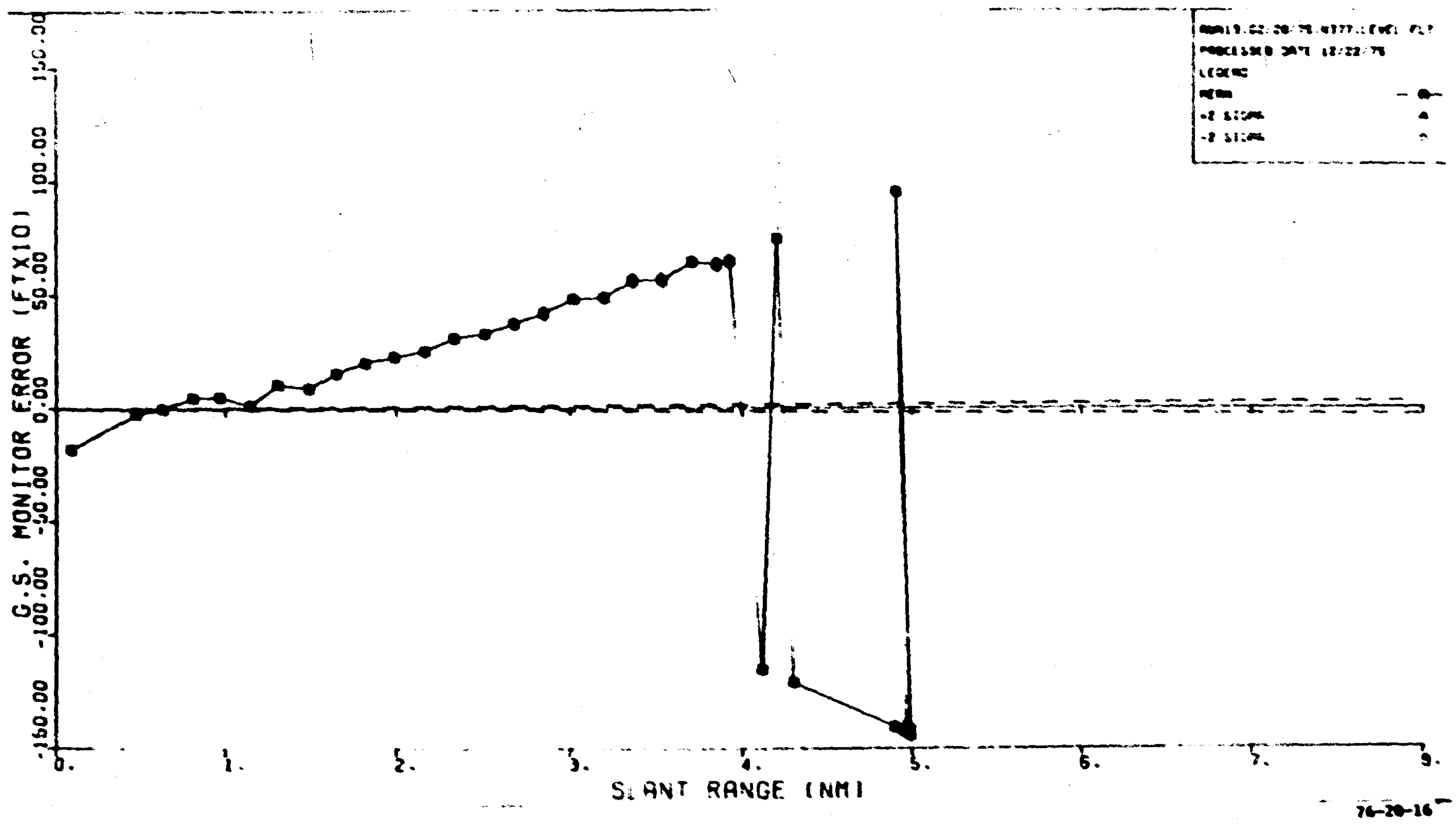


FIGURE A-16. ERROR DATA IN TERMS OF ALTITUDE FEET OFFSET FOR N-377 FLYING AT THE 230 FEET LEVEL ALTITUDE FLIGHT PATH ALONG THE 3° FINAL APPROACH PATH

APPENDIX B

F AND t TESTS' RESULTS OF EACH FLIGHT PERIOD, BETWEEN SOME FLIGHT PERIODS OF THE SAME AIRCRAFT AND BETWEEN THE AIRCRAFT OF SOME FLIGHT PERIODS.

This appendix contains all the results of the F and t tests performed on the reduced error data in this report. The F test concerns the reduced error data's variances to see if they are from equivalent populations. If the F test is passed, then the t test is applied to the error data means to determine if they are from equivalent populations. If both F and t tests indicate non-significance then that error data were from equivalent populations. The Westinghouse Electric Company Glide Slope Monitor Subsystem is then said to be yielding reproducible measurements for those particular error data bins and the particular data collection periods.

In each of F and t tests, first look at the computed F value. Its magnitude should be anywhere between the critical upper and lower limits at the desired confidence of either 0.95 or 0.99. This yields a non-significant (NS) effect on the data population, which is the desired result, indicating the tested data are from equivalent populations and further testing should be done. If a significant (S) determination was made, then no further testing of that data are necessary and the data are not from equivalent populations.

In applying the t test to NS tested error data, the absolute value of the computed T value is tested against the critical T values at the respective 0.95 or 0.99 confidence level. If the computed T value is less than the critical T value, the tested error data are determined to be from equivalent populations and, consequently, NS. However, if the absolute value of the computed T value is $\geq$ the critical T value; the tested error data are S. Therefore, they are not from equivalent populations.

The results of the F and t tests were generally mixed along the Slant Range axis, some data bins had means which were from similar data populations while other data bins had means which were from dissimilar data populations. Throughout the F and t test results there was, in general, twice the amount of dissimilar data means. There was no correlation between the F and t tests relating to particular Slant Range data bins. The F and t test results show there is a question as to repeatability in the Glide Slope Monitor Subsystem data.

TABLE B-1. F AND t TESTS

A. Results for the December 20, 1974 flight period of N-377 on the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
12 15 75

S- SIGNIFICANT DIFFERENCE BETWEEN BINS

BIN SIZE	ERROR OF GLIDE SLOPE (DEG.) Runs 7 and 8 12/20/74 NO. OF SCANS IN BIN	MEAN	STD DEV.	ERROR OF GLIDE SLOPE (DEG.) Runs 9 and 10 12/20/74 NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	T-TEST COMPUTED T VALUE	T-TEST CRITICAL T VALUE .95	CRITICAL T VALUE .99	F-TEST COMPUTED F VALUE	CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0. -0.99	14	-0.7902	1.822	12	-0.5860	1.308	24.	-0.323 NS	2.064 NS	2.797	1.941	0.294 NS	3.396	0.193 NS	5.174
1.00-1.99	14	-0.2345	0.064	14	-0.2401	0.065	26.	0.231 NS	2.056 NS	2.779	0.978	0.321 NS	3.120	0.218 NS	4.582
2.00-2.99	14	-0.2140	0.037	13	-0.2410	0.058	25.	1.456 NS	2.060 NS	2.787	0.421	0.308 NS	3.244	0.206 NS	4.845
3.00-3.99	14	-0.2345	0.039	12	-0.4529	1.585	24.	0.517 S	2.064 S	2.797	0.001	0.294 S	3.396	0.193 S	5.174
4.00-4.99	14	-0.1924	0.067	11	-0.3939	1.265	23.	0.599 S	2.069 S	2.807	0.003	0.279 S	3.588	0.179 S	5.598
5.00-5.99	11	-0.1922	0.081	10	-0.1812	0.091	19.	-0.293 NS	2.093 NS	2.861	0.797	0.252 NS	3.964	0.156 NS	6.417

B. Results for the January 10, 1975 flight period of N-377 on the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
12 16 75

S- SIGNIFICANT DIFFERENCE BETWEEN BINS

BIN SIZE	ERROR OF GLIDE SLOPE (DEG.) Runs 6 and 7 01/10/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	ERROR OF GLIDE SLOPE (DEG.) Runs 8 and 9 01/10/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	T-TEST COMPUTED T VALUE	T-TEST CRITICAL T VALUE .95	CRITICAL T VALUE .99	F-TEST COMPUTED F VALUE	CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .93	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0. -0.99	17	-0.2382	2.414	13	-0.0106	0.520	28.	-0.333 S	2.048 S	2.763	21.557	0.317 S	3.156	0.214 S	4.603
1.00-1.99	14	0.0444	0.131	15	0.0752	0.067	27.	-0.905 S	2.052 NS	2.771	3.758	0.332 S	3.016	0.224 NS	4.368
2.00-2.99	13	-0.0706	1.012	15	0.0764	0.052	26.	-0.563 S	2.056 S	2.779	381.967	0.328 S	3.050	0.226 S	4.428
3.00-3.99	12	0.0079	0.078	10	0.0749	0.062	20.	-2.191 S	2.086 NS	2.845	1.572	0.255 NS	3.916	0.158 NS	6.322

TABLE B-1. F AND t TESTS (continued)

C. Results for the January 30, 1975 flight period of N-377 on the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
12 4 75

ERROR OF GLIDE SLOPE (DEG.) Runs 2 and 3 01/30/75; ERROR OF GLIDE SLOPE (DEG.) Runs 4 and 5 01/30/75

S- SIGNIFICANT DIFFERENCE BETWEEN BINS

BIN SIZE	NO. OF SCANS IN BIN	MEAN	STD DEV.	NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	COMPUTED T VALUE	T-TEST CRITICAL T VALUE .95	CRITICAL T VALUE .99	COMPUTED F VALUE	F-TEST CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0. -0.99	15	-0.0036	0.053	11	-0.0832	[illegible]	24.	[illegible] NS	2.064 NS	2.797	[illegible]	[illegible] NS	3.555	[illegible] NS	5.534
1.00-1.99	11	-0.1930	[illegible]	[illegible]	-0.1997	0.058	22.	0.30[illegible] NS	2.074 NS	2.819	0.75[illegible]	[illegible] NS	3.374	[illegible] NS	5.086
2.00-2.99	13	-0.2152	0.063	12	-0.2047	0.028	23.	-0.53[illegible] S	2.069 S	2.807	4.0[illegible]	[illegible] S	3.43	0.19[illegible] NS	5.236
3.00-3.99	12	-0.2010	[illegible]	14	-0.1847	0.051	24.	-0.77[illegible] NS	2.064 NS	2.797	1.274	[illegible] NS	3.201	0.2[illegible] NS	4.731
4.00-4.99	12	-0.1893	[illegible]	12	-0.1418	0.046	22.	-1.054 NS	2.074 NS	2.819	0.859	[illegible] NS	3.478	0.1[illegible] NS	5.327

D. Results for the January 29, 1975 flight period of N-9093P on the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
12 10 75

ERROR OF GLIDE SLOPE (DEG.) Runs 8 and 9 01/29/75; ERROR OF GLIDE SLOPE (DEG.) Runs 10 and 11 01/29/75

S- SIGNIFICANT DIFFERENCE BETWEEN BINS

BIN SIZE	NO. OF SCANS IN BIN	MEAN	STD DEV.	NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	COMPUTED T VALUE	T-TEST CRITICAL T VALUE .95	CRITICAL T VALUE .99	COMPUTED F VALUE	F-TEST CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0. -0.99	13	-0.5949	2.112	11	-0.3138	0.188	22.	-0.438 S	2.074 S	2.819	126.394	0.276 S	3.621	0.177 S	5.661
1.00-1.99	18	-0.2587	0.125	17	-0.2296	0.103	33.	-0.750 NS	2.036 NS	2.736	1.486	0.364 NS	2.745	0.260 NS	3.846
2.00-2.99	17	-0.2315	0.093	15	-0.2296	0.101	30.	-0.056 NS	2.042 NS	2.750	0.839	0.342 NS	2.928	0.238 NS	4.229
3.00-3.99	14	-0.2479	0.104	17	-0.2251	0.093	29.	-0.646 NS	2.045 NS	2.756	1.251	0.350 NS	2.855	0.248 NS	4.040
4.00-4.99	4	-0.2933	0.115	15	-0.2692	0.154	17.	-0.290 NS	2.110 NS	2.698	0.558	0.236 NS	4.242	0.150 NS	6.680
5.00-5.99	0	-0.0000	-0.	4	-0.2268	0.082	2.	4.498 S	4.303 S	9.925	0.	-0.057 S	-17.443	-0.018 S	-55.552

E. Results for the February 4, 1975 flight period of N-9093P on the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
12 18 75

BIN SIZE	ERROR OF GLIDE SLOPE (DEG.) Runs 2 and 3 02/04/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	ERROR OF GLIDE SLOPE (DEG.) Runs 4 and 5 02/04/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	S- SIGNIFICANT DIFFERENCE BETWEEN BINS T-TEST COMPUTED T VALUE	T-TEST CRITICAL T VALUE .95	CRITICAL T VALUE .99	F-TEST COMPUTED F VALUE	CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0. -0.99	14	-0.2224	0.304	15	-0.2153	0.449	30.	-0.043 NS	2.042 NS	2.750	0.459	0.358 NS	2.791	0.236 NS	3.912
1.00-1.99	22	-0.2470	0.040	21	-0.4928	0.512	39.	2.149 S	2.023 S	2.709	0.006	0.402 S	2.484	0.298 S	3.359
2.00-2.99	21	-0.2381	0.072	20	-0.3030	0.451	39.	0.719 S	2.023 S	2.709	0.026	0.399 S	2.509	0.294 S	3.402
3.00-3.99	13	-0.2632	0.052	21	-0.2459	0.069	32.	-0.504 NS	2.038 NS	2.741	0.572	0.374 NS	2.676	0.272 NS	3.678
4.00-4.99	10	-0.0000	-0.	20	-0.2255	0.053	28.	13.254 S	2.048 S	2.763	0.	0.347 S	2.803	0.247 S	4.063
5.00-5.99	9	-0.0000	-0.	17	-0.2139	0.132	24.	4.804 S	2.064 S	2.797	0.	0.320 S	3.125	0.221 S	4.521
6.00-6.99	9	-0.0000	-0.	15	-0.1952	0.104	21.	5.184 S	2.080 S	2.831	0.	0.296 S	3.382	0.199 S	5.031
7.00-7.99	3	-0.0000	-0.	8	-0.3050	0.185	9.	0.054 S	2.262 S	3.250	0.	0.153 S	6.541	0.081 S	12.404

F. Results for the February 6, 1975 flight period of N-9093P on the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
12 19 75

BIN SIZE	ERROR OF GLIDE SLOPE (DEG.) Runs 3 and 4 02/06/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	ERROR OF GLIDE SLOPE (DEG.) Runs 5 and 6 02/06/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	S- SIGNIFICANT DIFFERENCE BETWEEN BINS T-TEST COMPUTED T VALUE	T-TEST CRITICAL T VALUE .95	CRITICAL T VALUE .99	F-TEST COMPUTED F VALUE	CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0. -0.99	12	-0.1231	[illegible]	12	-0.1222	[illegible]	22.	[illegible] S	2.074 NS	2.819	2.863	0.280 NS	3.470	0.188 NS	5.327
1.00-1.99	15	[illegible]	0.259	15	[illegible]	[illegible]	29.	[illegible] S	2.045 NS	2.756	[illegible]	[illegible] S	[illegible]	0.262 NS	[illegible]
2.00-2.99	15	[illegible]	[illegible]	13	[illegible]	[illegible]	26.	[illegible] S	2.056 NS	2.779	[illegible]	[illegible] NS	[illegible]	0.230 NS	4.703
3.00-3.99	15	[illegible]	[illegible]	13	[illegible]	[illegible]	26.	[illegible] S	2.056 NS	2.779	[illegible]	[illegible] NS	[illegible]	0.230 NS	4.703
4.00-4.99	13	[illegible]	[illegible]	13	[illegible]	[illegible]	24.	[illegible] S	2.064 NS	2.797	[illegible]	[illegible] NS	[illegible]	[illegible] NS	[illegible]
5.00-5.99	4	[illegible]	0.154	2	[illegible]	[illegible]	4.	[illegible] S	2.776 NS	4.604	[illegible]	[illegible] NS	[illegible]	[illegible] NS	[illegible]

TABLE B-1. F AND t TESTS (continued)

G. Results for the February 7, 1975 flight period of N-9093P on the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
12 21 75

S- SIGNIFICANT DIFFERENCE BETWEEN BINS

BIN SIZE	ERROR OF GLIDE SLOPE (DEG.) Runs 7 and 8 02/07/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	ERROR OF GLIDE SLOPE (DEG.) Runs 10 and 11 02/07/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	T-TEST COMPUTED T VALUE	CRITICAL T VALUE .95	CRITICAL T VALUE .99	F-TEST COMPUTED F VALUE	CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0. -0.99	11	-0.1145	0.298	13	0.0879	2.046	22.	-0.324 S	2.074 S	2.819	0.021	0.296 S	3.374	0.197 S	5.086
1.00-1.99	15	-0.1869	0.226	10	-0.2121	0.156	23.	0.307 NS	2.069 NS	2.807	2.092	0.253 NS	3.802	0.164 NS	6.097
2.00-2.99	15	-0.1642	0.098	12	-0.2099	0.105	25.	1.164 NS	2.060 NS	2.787	0.867	0.297 NS	3.363	0.196 NS	5.111
3.00-3.99	14	-0.2087	0.099	7	-0.1948	0.079	19.	-0.321 NS	2.093 NS	2.861	1.574	0.187 NS	5.334	0.100 NS	9.961
4.00-4.99	14	-0.2110	0.161	7	-0.2629	0.140	19.	0.723 NS	2.093 NS	2.861	1.327	0.187 NS	5.334	0.100 NS	9.961
5.00-5.99	4	-0.2260	0.074	6	-0.2954	0.047	8.	1.839 NS	2.306 NS	3.355	2.545	0.129 NS	7.764	0.060 NS	16.530
6.00-6.99	0	-0.0000	-0.	2	-0.3424	0.068	0.	0. S	20.768 S	102.805	0.	-0.002 S	647.790	-0.000 S	211.000

H. Results for the January 30, 1975 flight period of N-377 0.35° below the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
12 8 75

S- SIGNIFICANT DIFFERENCE BETWEEN BINS

BIN SIZE	ERROR OF GLIDE SLOPE (DEG.) Runs 8 and 9 01/30/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	ERROR OF GLIDE SLOPE (DEG.) Runs 10 and 11 01/30/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	T-TEST COMPUTED T VALUE	CRITICAL T VALUE .95	CRITICAL T VALUE .99	F-TEST COMPUTED F VALUE	CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0. -0.99	13	-1.2533	1.774	12	-0.7310	1.344	23.	-0.824 NS	2.069 NS	2.807	1.743	.292 NS	3.430	0.19[illegible] NS	5.236
1.00-1.99	12	-0.3669	0.060	13	-0.3109	0.052	23.	-2.516 S	2.069 NS	2.807	1.330	.301 NS	3.325	0.2[illegible] NS	4.996
2.00-2.99	11	-0.2770	0.060	12	-0.2658	0.036	21.	-0.553 NS	2.080 NS	2.831	2.759	.284 NS	3.526	0.185 NS	5.418
3.00-3.99	12	-0.2953	0.050	9	-0.2242	0.121	19.	-1.845 S	2.093 NS	2.861	0.167	.235 S	4.247	0.141 NS	7.113
4.00-4.99	10	-0.2961	0.035	11	-0.2374	0.104	19.	-1.699 S	2.093 S	2.861	0.111	0.265 S	3.779	0.169 S	5.968

PERMANENT READ REDUNDANCY U4.TOB

EXECUTION TERMINATED.

TABLE B-1. F AND t TESTS (continued)

I. Results for the February 20, 1975 flight period of N-377 on the 1508 feet level altitude flight along the Final Approach Path

PROCESSED DATE
MONTH DAY YEAR
12 2 75

S- SIGNIFICANT DIFFERENCE BETWEEN BINS

BIN SIZE	ERROR OF GLIDE SLOPE (DEG.) Runs 3 and 4 02/20/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	ERROR OF GLIDE SLOPE (DEG.) Runs 9 and 10 02/20/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	COMPUTED t VALUE	T-TEST CRITICAL T VALUE .95	CRITICAL T VALUE .99	COMPUTED F VALUE	F-TEST CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0. -0.99	6	25.6128	24.661	9	33.6062	21.012	13.	-0.675 NS	2.160 NS	3.012	1.377	0.208 NS	4.817	0.120 NS	8.302
1.00-1.99	7	-6.6528	1.258	6	-7.3119	0.976	11.	1.041 NS	2.201 NS	3.106	1.661	0.143 NS	6.978	0.069 NS	14.513
2.00-2.99	8	-4.3836	2.282	8	-3.7308	2.928	14.	-0.497 NS	2.145 NS	2.977	0.608	0.200 NS	4.995	0.113 NS	8.885
3.00-3.99	9	0.0561	0.777	8	-0.5247	0.459	15.	1.844 NS	2.131 NS	2.947	2.867	0.204 NS	4.899	0.115 NS	8.678
4.00-4.99	11	-0.4618	0.081	12	-0.5317	0.106	21.	1.762 NS	2.080 NS	2.831	0.592	0.284 NS	3.526	0.185 NS	5.418
5.00-5.99	12	-0.2452	0.163	10	-0.2447	0.112	20.	-0.009 NS	2.086 NS	2.845	2.118	0.255 NS	3.918	0.158 NS	6.322
6.00-6.99	12	0.3666	0.127	10	0.3356	0.158	20.	0.511 NS	2.086 NS	2.845	0.644	0.255 NS	3.918	0.158 NS	6.322
7.00-7.99	1	0.7286	-0.	4	0.6334	0.049	3.	1.756 NS	3.182 NS	5.841	0.	-0. NS	-0.	-0. NS	-0.

J. Results for different flight periods of N-377 on the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
2 27 76

BIN SIZE	ERROR OF GLIDE SLOPE (DEG.) Runs 7 and 8 12/2 /76 NO. OF SCANS IN BIN	MEAN	STD DEV.	ERROR OF GLIDE SLOPE (DEG.) Runs 4 and 5 1 3 /75 NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	COMPUTED t VALUE	T-TEST CRITICAL T VALUE .95	CRITICAL T VALUE .99	COMPUTED F VALUE	F-TEST CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0. -0.99	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] NS	[illegible]
1.00-1.99	16	[illegible]	[illegible]	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.763	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.00-2.99	16	[illegible]	[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.756	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.00-3.99	16	[illegible]	[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.756	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4.00-4.99	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] NS	[illegible]	2.797	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

TABLE B-1. F AND t TESTS (continued)

K. Results for different flight periods of N-9091P on the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
3 1 76

S– SIGNIFICANT DIFFERENCE BETWEEN BINS

BIN SIZE	ERROR OF GLIDE SLOPE (DEG.) Runs 10 and 11 01/20/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	ERROR OF GLIDE SLOPE (DEG.) Runs 10 and 11 2/07/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	COMPUTED T VALUE	T-TEST CRITICAL T VALUE .95	CRITICAL T VALUE .99	COMPUTED F VALUE	F-TEST CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0.-0.99	11	-0.3130	0.188	12	-0.1947	0.193	21.	-1.497 NS	2.080 NS	2.831	0.946	0.284 NS	3.826	0.185 NS	5.418
1.00-1.99	19	-0.2296	0.103	10	-0.2121	0.156	25.	-0.353 NS	2.060 NS	2.787	0.432	0.269 NS	3.769	0.167 NS	5.992
2.00-2.99	15	-0.2296	0.101	12	-0.2099	0.105	25.	-0.692 NS	2.060 NS	2.787	0.921	0.297 NS	3.363	0.196 NS	5.111
3.00-3.99	17	-0.2251	0.093	7	-0.1948	0.079	22.	-0.757 NS	2.074 NS	2.819	1.376	0.191 NS	5.249	0.102 NS	9.789
4.00-4.99	15	-0.2692	0.144	7	-0.2029	0.140	20.	-0.092 NS	2.086 NS	2.845	1.204	0.189 NS	5.301	0.101 NS	9.887
5.00-5.99	4	-0.2268	0.082	6	-0.2954	0.047	8.	1.702 NS	2.306 NS	3.355	3.132	0.129 NS	7.764	0.060 NS	16.530
6.00-6.99	0	-0.0000	-0.000	2	-0.3424	0.068	0.	0. S	20.768 S	102.805	0.	-0.002 S	647.790	-0.000 S	211.000

STANDARD DEVIATION - 2 SIGMA

L. Results for different flight periods and different aircraft on the 3° ILS Glide Slope

PROCESSED DATE
MONTH DAY YEAR
3 2 76

S– SIGNIFICANT DIFFERENCE BETWEEN BINS

BIN SIZE	ERROR OF GLIDE SLOPE (DEG.) Runs 7 and 8 12/20/74 NO. OF SCANS IN BIN	MEAN	STD DEV.	ERROR OF GLIDE SLOPE (DEG.) Run 10 and 11 2/07/75 NO. OF SCANS IN BIN	MEAN	STD DEV.	DF	COMPUTED T VALUE	T-TEST CRITICAL T VALUE .95	CRITICAL T VALUE .99	COMPUTED F VALUE	F-TEST CRITICAL F VALUE LOWER LIMIT .95	CRITICAL F VALUE UPPER LIMIT .95	CRITICAL F VALUE LOWER LIMIT .99	CRITICAL F VALUE UPPER LIMIT .99
0.-0.99	11	-0.3415	0.382	12	-0.1947	0.193	21.	-1.180 S	2.080 NS	2.831	3.904	0.284 S	3.526	0.185 NS	3.418
1.00-1.99	14	-0.2345	0.064	10	-0.2121	0.156	22.	-0.486 S	2.074 NS	2.819	0.170	0.261 S	3.835	0.162 NS	6.162
2.00-2.99	14	-0.2140	0.037	12	-0.2099	0.105	24.	-0.136 S	2.064 S	2.797	0.126	0.294 S	3.396	0.193 S	5.174
3.00-3.99	14	-0.2345	0.039	7	-0.1948	0.077	19.	-1.565 NS	2.093 NS	2.861	0.237	0.187 NS	5.334	0.100 NS	9.961
4.00-4.99	14	-0.1924	0.067	7	-0.2629	0.140	19.	1.587 NS	2.093 NS	2.861	0.229	0.187 NS	5.334	0.100 NS	9.961
5.00-5.99	11	-0.1922	0.081	6	-0.2954	0.047	15.	2.834 S	2.131 NS	2.947	3.067	0.151 NS	6.619	0.073 NS	13.618
6.00-6.99	4	0.0367	0.714	2	-0.3424	0.068	4.	0.651 NS	2.776 NS	4.604	110.025	0.001 NS	864.163	0.000 NS	615.000

STANDARD DEVIATION - 2 SIGMA